U.S. FISH AND WILDLIFE SERVICE
SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

SCIENTIFIC NAME: *Gila robusta*

COMMON NAME: Roundtail Chub, Lower Colorado River Basin Distinct Population Segment

LEAD REGION: 2

INFORMATION CURRENT AS OF: April 12, 2010

STATUS/ACTION

___ Species assessment - determined we do not have sufficient information on file to support a proposal to list the species and, therefore, it was not elevated to Candidate status
___ New candidate
_X_ Continuing candidate
___ Non-petitioned
_X_ Petitioned - Date petition received: April 14, 2003
__ 90-day positive - FR date: July 12, 2005
__ 12-month warranted but precluded - FR date: July 7, 2009
__ Did the petition request a reclassification of a listed species?

FOR PETITIONED CANDIDATE SPECIES:
a. Is listing warranted (if yes, see summary of threats below)? yes
b. To date, has publication of a proposal to list been precluded by other higher priority listing actions? yes
c. If the answer to a. and b. is "yes", provide an explanation of why the action is precluded.
Higher priority listing actions, including court-approved settlements, court-ordered statutory deadlines for petition findings and listing determinations, emergency listing determinations, and responses to litigation, continue to preclude the proposed and final listing rules for the species. We continue to monitor populations and will change its status or implement an emergency listing if necessary. For information on listing actions taken, see the discussion of "Progress on Revising the Lists" in the current CNOR, which can be viewed at our Internet website (***http://endangered.fws.gov/***).

___ Listing priority change
Former LP: ___
New LP: ___

Date when the species first became a Candidate (as currently defined): July 7, 2009

___ Candidate removal: Former LPN: ___
___ A – Taxon is more abundant or widespread than previously believed or not subject to

the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.

____U – Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.

___ F – Range is no longer a U.S. territory.

___ I – Insufficient information exists on biological vulnerability and threats to support listing.

___ M – Taxon mistakenly included in past notice of review.

___ N – Taxon does not meet the Act's definition of "species."

___ X – Taxon believed to be extinct.

ANIMAL/PLANT GROUP AND FAMILY: Fishes - Cyprinidae

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE: AZ, NM

CURRENT STATES/COUNTIES/TERRITORIES/COUNTRIES OF OCCURRENCE: AZ, NM

LAND OWNERSHIP: Estimated percentage from Voeltz (2002): 48 percent Federal, 18 percent State, 11 percent private, and 24 percent Tribal.

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BIOLOGICAL INFORMATION

Species Description

The roundtail chub is a cyprinid fish (member of Cyprinidae, the minnow family) with a streamlined body shape. Color in roundtail chub is usually olive gray to silvery, with the belly lighter, and sometimes with dark blotches on the sides. Roundtail chubs are generally 9 to 14 in. (25 to 35 cm) in length, but can reach 20 in. (50 cm) (Minckley 1973, pp. 101–103; Sublette *et al.* 1990, pp. 126–129; Propst 1999, pp. 23–25; Minckley and Demaris 2000, pp. 251– 256; Voeltz 2002, pp. 8–11).

Taxonomy

Baird and Girard first described roundtail chub from specimens collected from the Zuni River in northeastern Arizona and northwestern New Mexico (Baird and Girard 1853, pp. 368–369). Roundtail chub has been recognized as a distinct species since the 1800s (Miller 1945, p. 104; Holden 1968, pp. 27–28; Rinne 1969, pp. 27–42; Holden and Stalnaker 1970, p. 409; Rinne 1976, pp. 87–91; Smith *et al.* 1979, p. 623; DeMarais 1986, p. iii; Douglas *et al.* 1989, p. 653; Rosenfeld and Wilkinson 1989, p. 232; DeMarais 1992, pp. 63–64; Dowling and DeMarais

1993, p. 444; Douglas *et al.* 1998, p. 169; Minckley and DeMarais 2000, p. 255; Gerber *et al.* 2001, p. 2028), and is currently recognized as a species by the American Fisheries Society (Nelson *et al.* 2004, p. 71). The chubs of the genus *Gila* in the lower Colorado River basin are all closely related and are often regarded as a species complex (Minckley 1973, p. 101; DeMarais 1992, p. 150; Dowling and DeMarais 1993, p. 444; Minckley and DeMarais 2000, p. 251; Gerber *et al.* 2001, p. 2028).

Habitat/Life History

Roundtail chubs in the lower Colorado River basin are found in cool to warm waters of rivers and streams, and often occupy the deepest pools and eddies of large streams (Minckley 1973, p. 101; Brouder *et al.* 2000, pp. 6–8; Minckley and DeMarais 2000, p. 255; Bezzerides and Bestgen 2002, pp. 17– 19). Although roundtail chubs are often associated with various cover features, such as boulders, vegetation, and undercut banks, they are less likely to use cover than other related species such as the headwater chub (*Gila nigra*) and Gila chub (*Gila intermedia*) (Minckley and DeMarais 2000, p. 2145). Water temperatures of habitats occupied by roundtail chub vary between 32 to 90 degrees Fahrenheit (°F) (0 degrees and greater than 32 degrees Celsius (°C)) (Bestgen 1985, p. 14). Carveth *et al.* (2006, p. 1435) reported the upper thermal tolerance of roundtail chub to be 97.9 °F (36.6 °C); spawning has been documented from 57 to 75 °F (14 to 24 °C) (Bestgen 1985, p. 14; Kaeding et al. 1990, p. 139; Brouder *et al.* 2000, p. 13). Spawning occurs from February through June in pool, run, and riffle habitats, with slow to moderate water velocities (Neve 1976, p. 32; Bestgen 1985, pp. 56–67; Propst 1999, p. 24; Brouder *et al.* 2000, p. 12; Voeltz 2002, p. 16). Roundtail chubs live for 5 to 7 years and spawn from age two on (Bestgen 1985, p. 62; Brouder *et al.* 2000, p. 12). Roundtail chubs are omnivores, consuming foods proportional to their availability, including aquatic and terrestrial invertebrates, aquatic plants, detritus, and fish and other vertebrates; algae and aquatic insects can be major portions of the diet (Bestgen 1985, pp. 46–53; Schreiber and Minckley 1981, pp. 409, 415; Propst 1999, p. 24).

Historical Range/Distribution

The historical distribution of roundtail chub in the lower Colorado River basin is poorly documented because there were few early collections, and perhaps more importantly, because many populations of native fish, including roundtail chub, were likely lost prior to early comprehensive fish surveys because habitat-altering actions (e.g., dewatering, livestock grazing, mining) were widespread, and had already severely altered aquatic habitats (Girmendonk and Young 1997, p. 50; Minckley 1999, p. 179; Voeltz, 2002, p. 19). Roundtail chub was historically considered common throughout its range (Minckley 1973, p. 101; Holden and Stalnaker 1975, p. 222; Propst 1999, p. 23). Voeltz (2002), estimating historical distribution based on museum collection records, agency database searches, literature searches, and discussion with biologists, found that roundtail chub in the lower Colorado River basin was historically found in the Gila and Zuni rivers in New Mexico; the Black, Colorado (though likely only as a transient), Little Colorado, Bill Williams, Gila, San Francisco, San Carlos, San Pedro, Salt, Verde, White, and Zuni rivers in Arizona: and numerous tributaries within those basins. Voeltz (2002, p. 83) estimated the lower Colorado River basin roundtail chub historically occupied approximately 2,796 mi (4,500 km) of rivers and streams in Arizona and New Mexico. Although roundtail chubs were never collected from the Colorado River or San Pedro River basin in Mexico, they may have occurred in these areas based on records near the international border in the lower Colorado River and upper San Pedro River and the occurrence of suitable habitat in these streams in Mexico (Voeltz 2002, p. 20).

Miller (1961) first comprehensively documented the decline of fishes of the southwestern United States in 1961, but interestingly, F.M. Chamberlain made similar observations in Arizona in 1904; roundtail chub was included in these assessments and in subsequent evaluations of imperiled fish species of the region (Miller 1961, pp. 373–379; Miller 1972, p. 242; Deacon *et al.* 1979, p. 34; Minckley 1999, pp. 215–218). The decline of the species has been documented both in the scientific peer reviewed literature (Bestgen and Propst 1989, p. 402) and in State agency reports (Girmendonk and Young 1997, p. 49; Propst 1999, p. 23; Brouder *et al.* 2000, p. 1; Bezzerides and Bestgen 2002, pp. iii–iv; Voeltz 2002, p. 83). Roundtail chub is considered vulnerable by the American Fisheries Society (Jenks *et al.* 2008, p. 390).

Current Range/Distribution

Roundtail chub in the lower Colorado River basin in Arizona currently occurs in two tributaries of the Little Colorado River (Chevelon and East Clear creeks); several tributaries of the Bill Williams River basin (Boulder, Burro, Conger, Francis, Kirkland, Sycamore, Trout, and Wilder creeks); the Salt River and four of its tributaries (Ash Creek, Black River, Cherry Creek and Salome Creek); the Verde River and five of its tributaries (Fossil, Oak, Roundtree Canyon, West Clear, and Wet Beaver creeks); Aravaipa Creek (a tributary of the San Pedro River); Eagle Creek (a tributary of the Gila River); and in New Mexico, in the upper Gila River (Voeltz 2002, pp. 82–83; the upper Gila River is used in this document to denote that portion of the Gila River basin in New Mexico). The Salt River and Verde River are occupied in several reaches that are fragmented and separated by two large dams and reservoirs on the Verde River, and four large dams and reservoirs on the Salt River. Roundtail chubs also occur in canals in Phoenix that are fed by the lower Salt and Verde Rivers. Roundtail chubs inhabit several streams in the Salt River drainage, although survey information on the San Carlos Apache Reservation and White Mountain Apache Reservation is proprietary and confidential, and their status is not currently known; these streams include Canyon, Carrizo, Cedar, Cibecue, and Corduroy creeks, and the White River (Voeltz 2002, pp. 82–83).

The Arizona Game and Fish Department (AGFD) conducted a comprehensive status review of roundtail and headwater chub (Voeltz 2002) in the lower Colorado River basin that included a review of all available current and historical survey records and estimated historical and current range of roundtail chub using information from museum collections, agency databases, records found in literature, and consultation with experts. The report found that roundtail chub populations and distribution had declined significantly from historical levels. Based on Voeltz (2002), roundtail chub is known to occupy only 18 percent of its former range in the lower Colorado River basin; status in an additional 14 percent of its range is unknown. Based on the best available scientific information in Voeltz (2002), the roundtail chub in the lower Colorado River basin appears to occupy about 18 to 32 percent of its former range (approximately 497 mi (800 km) out of the 2,796 mi (4,500 km)) considered to be formerly occupied) in Arizona and New Mexico. We now consider the Colorado River in the lower Colorado River basin to be outside the historical range of the species (Voeltz considered it to have been occupied); given this, roundtail chub has been extirpated from 672 mi (965 km) of 2,197 mi (3,535 km; approximately 60 percent) of its formerly occupied range. Of the populations for which status and threat information is available, all but one of the remaining natural populations is considered threatened by both the presence of nonnative species and habitat-altering land uses.

Population Estimates/Status

In the report, Voeltz (2002) used a classification system to report status and threat information. Populations were defined as an occurrence at a stream specific locality. A population was considered ‘‘stable-secure,’’ ‘‘stable-threatened,’’ or ‘‘unstable-threatened,’’ based on abundance, population trend, and threat information for the locality (see Table 1, Voeltz 2002, p. 5). Voeltz (2002, p. 5) considered a population ‘‘extirpated’’ if the species was no longer believed to occupy the site, and ‘‘unknown’’ if there are too few data to determine status. Note that the term ‘‘threatened’’ as used by Voeltz (2002, p. 5) is not the definition of ‘‘threatened’’ used in the Endangered Species Act (Act) in which a species is likely to become endangered in the foreseeable future, but rather is an estimate of the likelihood that a population is likely to become extirpated. Of 40 populations of roundtail chub in the lower Colorado River basin identified in the report, Voeltz (2002, pp. 82–87) found that none were ‘‘stable-secure,’’ six were ‘‘stable-threatened,’’ 13 were ‘‘unstable-threatened,’’ 10 were ‘‘extirpated,’’ and 11 were of ‘‘unknown’’ status. Populations with an ‘‘unknown’’ status in Voeltz (2002) included nine populations wholly or partly on Tribal lands. Tribes are sovereign nations and survey data is proprietary and confidential, but existing survey information for these streams was provided and indicated occupancy. The remaining two populations with ‘‘unknown’’ status lacked sufficient information to assign a category.

Table 1. Definitions of status description categories used to describe the status of roundtail chub populations (from Voeltz 2002).

Status	***Definition***
Stable-Secure	Chubs are abundant or common, data over the past 5-10 years shows a stable, reproducing population with successful recruitment; no impacts from nonnative aquatic species exist; and no current or future habitat altering land or water uses were identified.
Stable-Threatened	Chubs are abundant or common, data over the past 5-10 years shows a reproducing population, although recruitment may be limited; predatory or competitive threats from nonnative aquatic species exist; and/or some current or future habitat altering land or water uses were identified.
Unstable-Threatened	Chubs are uncommon or rare with a limited distribution; data over the past 5-10 years shows a declining population with limited

	recruitment; predatory or competitive threats from nonnative aquatic species exist; and/or serious current or future habitat altering land or water uses were identified.
Extirpated	Chubs are no longer believed to occur in the system.
Unknown	Lack of data precludes determination of status.

We have updated this assessment with new data from various sources, particularly Cantrell (2009) as provided in Table 2 below. It is important to recognize that these status categories are qualitative, and based on very limited data in most instances. We have very little information on the population size, length of the stream reach, survivorship, recruitment (survival of young to Age 2, reproductive age), or age structure of these populations. These categories are also often based on only a few surveys conducted over decadal time scales. We now consider 1 population ‘‘stable-secure,’’ 8 populations ‘‘stable-threatened,’’ 13 populations ‘‘unstable-threatened,’’ and 9 populations ‘‘unknown.’’ Ten populations remain extirpated although we now consider what was called a population in the Colorado River to have been occupied only by transient individuals. In the nine populations with ‘‘unknown’’ status, two (Ash Creek and Roundtree Creek) are newly established via translocation and have not been extant long enough to determine successful establishment. Information on the Black River and Conger Creek provided since the 2002 report resulted in re-categorization of both of those sites from ‘‘unknown’’ to ‘‘stable-threatened’’ and for re-categorization of Eagle Creek from ‘‘unknown’’ to ‘‘unstable-threatened.’’ Improved status at Fossil Creek that allows that population to reach ‘‘stable-secure’’ is due to removal of the power plant and associated structures, construction of a new fish barrier, and chemical renovation to remove nonnative fish species. Recent surveys have confirmed some of the information in Voeltz’s 2002 status review; in the upper Black River, Chevelon Creek, and East Clear Creek, the species persists in the presence of abundant nonnative predators, and apparently reproduces successfully, but distribution appears limited, abundance is unknown, and other signs, such as abundance of other native fish species, indicate these native fisheries are deteriorating (AGFD 2005a, p. 4; 2005b, pp. 4–5; Clarkson and Marsh 2005a, pp. 6–8; 2005b, pp. 6–7). Other roundtail chub populations in waters with abundant nonnative predators are less able to reproduce successfully and the particular circumstances at these three sites are worth further investigation. Roundtail chub in the lower Colorado River basin in New Mexico may now be extirpated. The species has long been considered extirpated in many Gila River tributaries in New Mexico, and has become very rare in the mainstem Gila River (Carman 2006, pp. 9, 18).

Table 2. Summary of roundtail chub status and threats by stream reach (Voeltz 2002, Cantrell 2009, Service files).

Location	Current Status	Regional historical or current threats
Management Area A—Gila River Basin		
Aravaipa Creek	ST	Factor A: Water diversions, groundwater pumping, recreation, mining, livestock grazing, road use Factor C: Nonnative species
Blue River	E	Factor A: Water diversions, groundwater pumping, logging and fuel wood cutting, recreation, livestock grazing, road use Factor C: Nonnative species
Eagle Creek	UT	Factor A: Dams, water diversions, groundwater pumping, recreation, mining, livestock grazing Factor C: Nonnative species
San Francisco River	E	Factor A: Dams, water diversions, groundwater pumping, dewatering, logging and fuel wood cutting, recreation, mining, urban and agricultural development, livestock grazing Factor C: Nonnative species
Upper Gila River	UT	Factor A: Dams, water diversions, groundwater pumping, dewatering, logging and fuel wood cutting, recreation, mining, urban and agricultural development, livestock grazing Factor C: Nonnative species
Lower Gila River	E	Factor A: Dams, water diversions, groundwater pumping, dewatering, logging and fuel wood cutting, recreation, mining, urban and agricultural development, livestock grazing Factor C: Nonnative species
San Pedro River	E	Factor A: Dams, water diversions, groundwater pumping, dewatering, logging and fuel wood cutting, recreation, mining, urban and agricultural development, livestock grazing Factor C: Nonnative species
Management Area A—Salt River Basin		
Ash Creek	UN	Factor A: Recreation, logging and fuel wood cutting, livestock grazing
Black River	ST	Factor A: Water diversions, groundwater pumping, recreation, livestock grazing, mining, logging and fuel wood cutting, urban and agricultural development Factor C: Nonnative species

Canyon Creek	UN	Factor A: Livestock grazing, recreation, limited fuelwood harvest, limited agriculture, fisheries and wildlife management, and localized municipal, urban and rural development and associated water use Factor C: Nonnative species
Carrizo Creek	UN	Factor A: Livestock grazing, recreation, limited fuelwood harvest, limited agriculture, fisheries and wildlife management, and localized municipal, urban and rural development and associated water use Factor C: Nonnative species
Cedar Creek	UN	Factor A: Livestock grazing, recreation, limited fuelwood harvest, limited agriculture, fisheries and wildlife management, and localized municipal, urban and rural development and associated water use Factor C: Nonnative species
Cherry Creek	ST	Factor A: Water diversions, groundwater pumping, mining, recreation, livestock grazing, mining, logging and fuel wood cutting, urban and agricultural development Factor C: Nonnative species
Cibecue Creek	UN	Factor A: Livestock grazing, recreation, limited fuelwood harvest, limited agriculture, fisheries and wildlife management, and localized municipal, urban and rural development and associated water use Factor C: Nonnative species
Corduroy Creek	UN	Factor A: Livestock grazing, recreation, limited fuelwood harvest, limited agriculture, fisheries and wildlife management, and localized municipal, urban and rural development and associated water use Factor C: Nonnative species
Salome Creek	UT	Factor A: Recreation, logging and fuel wood cutting, livestock grazing Factor C: Nonnative species
Salt River	UT	Factor A: Dams, water diversions, groundwater pumping, dewatering, logging and fuel wood cutting, recreation, mining, urban and agricultural development, livestock grazing Factor C: Nonnative species
White River	UN	Factor A: Water diversions, groundwater pumping, recreation, livestock grazing, mining, logging and fuel wood cutting, urban and agricultural development Factor C: Nonnative species
Management Area A—Verde River Basin		
Dry Beaver Creek	E	Factor A: Water diversions, dewatering, livestock grazing, logging and fuel wood cutting, recreation Factor C: Nonnative species

Fossil Creek	SS	Factor A: Water diversions, groundwater pumping, dewatering, mining, contaminants, urban and agricultural development, livestock grazing
Oak Creek	UT	Factor A: Water diversions, groundwater pumping, dewatering, mining, contaminants, urban and agricultural development, livestock grazing Factor C: Nonnative species
Roundtree Canyon	UN	Factor A: Recreation, logging and fuel wood cutting, livestock grazing
Verde River	ST	Factor A: Water diversions, groundwater pumping, dewatering, mining, contaminants, urban and agricultural development, livestock grazing Factor C: Nonnative species
West Clear Creek	ST	Factor A: Water diversions, dewatering, livestock grazing, logging and fuel wood cutting, recreation Factor C: Nonnative species
Wet Beaver Creek	UT	Factor A: Water diversions, dewatering, livestock grazing, logging and fuel wood cutting, recreation Factor C: Nonnative species
Management Area B—Bill Williams River Basin		
Big Sandy River	E	Factor A: Water diversions, groundwater pumping, recreation, mining, livestock grazing, residential development Factor C: Nonnative species
Bill Williams River	E	Factor A: Water diversions, groundwater pumping, recreation, mining, livestock grazing Factor C: Nonnative species
Boulder Creek	ST	Factor A: Groundwater pumping, recreation, livestock grazing, Factor C: Nonnative species
Burro Creek	UT	Factor A: Water diversions, groundwater pumping, recreation, mining, livestock grazing, residential development, contaminants Factor C: Nonnative species
Conger Creek	ST	Factor A: Groundwater pumping, mining, livestock grazing, recreation Factor C: Nonnative species
Francis Creek	UT	Factor A: Groundwater pumping, mining, livestock grazing, recreation Factor C: Nonnative species
Kirkland Creek	UT	Factor A: Groundwater pumping, recreation, mining, livestock grazing, residential development, contaminants Factor C: Nonnative species

Santa Maria River	UT	Factor A: Groundwater pumping, recreation, mining, livestock grazing, residential development, contaminants Factor C: Nonnative species
Sycamore Creek	UT	Factor A: Water diversions, groundwater pumping, recreation, mining, livestock grazing, residential development, contaminants Factor C: Nonnative species
Trout Creek	ST	Factor A: Water diversions, groundwater pumping, recreation, residential development Factor C: Nonnative species
Wilder Creek	UN	Factor A: Groundwater pumping, mining, livestock grazing, recreation Factor C: Nonnative species
Management Area C—Little Colorado River Basin		
Chevelon Creek	UT	Factor A: Dams, water diversions, groundwater pumping, dewatering, logging and fuel wood cutting, recreation, mining, urban and agricultural development, livestock grazing, contaminants Factor C: Nonnative species
East Clear Creek	UT	Factor A: Logging and fuel wood cutting, recreation, mining, livestock grazing, contaminants Factor C: Nonnative species
Little Colorado River	E	Factor A: Dams, water diversions, groundwater pumping, dewatering, logging and fuel wood cutting, recreation, mining, urban and agricultural development, livestock grazing Factor C: Nonnative species
Zuni River	E	Factor A: Water diversions, groundwater pumping, dewatering, mining, contaminants, urban and agricultural development, livestock grazing Factor C: Nonnative species

SS–Stable-Secure; ST–Stable-Threatened; UT–Unstable-Threatened; E–Extirpated; UN–Unknown

Populations of roundtail chub are found in five separate drainages that are isolated from one another (the Little Colorado River, Bill Williams River, Gila River, Salt River, and Verde River), and populations within the drainages have varying amounts of connectivity between them. Using large-scale watersheds, AGFD created ‘‘management areas’’ and ‘‘significant conservation units’’ based on currently occupied roundtail habitats. AGFD has utilized new genetic studies (Dowling et al. 2008; Schwemm 2006; See Table 2) to refine these management areas. Based on genetic similarity, the Verde, Salt, and Gila Rivers and their tributaries constitute Management Area A, the Bill Williams and its tributaries are Management Area B, and the Little Colorado River and its tributaries are Management Area C. Cantrell (2009, p. 9) also refined significant conservation units for management purposes based on genetic information (Dowling et al. 2008; Schwemm 2006); however the mechanism for selecting these units and determination of stability versus instability of a management area or significant conservation units was not clearly described.

DISTINCT POPULATION SEGMENT (DPS)

In the 2003 petition, we were asked to consider listing a DPS for the roundtail chub in the lower Colorado River basin (the Colorado River and its tributaries downstream of Glen Canyon Dam including the Gila and Zuni River basins in New Mexico). Per our November 5, 2007, stipulated settlement agreement, we re-evaluated our May 3, 2006, determination (71 FR 26007) that listing the roundtail chub population segment in the lower Colorado River basin was not warranted because it did not meet our definition of a DPS. Our July 9, 2009 finding determined that the lower Colorado River basin did meet the definition of a DPS as described below.

In accordance with our DPS Policy, this section details our analysis of the first two elements we consider in a decision regarding the status of a possible DPS as endangered or threatened under the Act. These elements are (1) the population segment's discreteness from the remainder of the species to which it belongs and (2) the significance of the population segment to the species to which it belongs.

Discreteness

The DPS policy's standard for discreteness requires an entity to be adequately defined and described in some way that distinguishes it from other representatives of its species. A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following two conditions: (1) It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors (quantitative measures of genetic or morphological discontinuity may provide evidence of this separation); or (2) it is delimited by international governmental boundaries within which significant differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist.

The historical range of roundtail chub included both the upper and lower Colorado River basins in the States of Wyoming, Utah, Colorado, New Mexico, Arizona, and Nevada (Propst 1999, p. 23; Bezzerides and Bestgen 2002, p. 25; Voeltz 2002, pp. 19–23), but the roundtail chub was likely only a transient in Nevada. Currently, roundtail chubs occur in both the upper and lower Colorado River basins in Wyoming, Utah, Colorado, New Mexico, and Arizona. Bezzerides and Bestgen (2002, p. 24) concluded that historically there were two discrete population centers, one in each of the lower and upper basins, and that these two population centers remain today. Numerous authors have noted that roundtail chub was very rare with few documented records in the mainstem Colorado River between the two basins (Minckley 1973, p. 102; Minckley 1979, p. 51; Valdez and Ryel 1994, pp. 5–10– 5–11; Minckley 1996, p. 75; Bezzerides and Bestgen 2002, pp. 24–25; Voeltz 2002, pp. 19, 112), so we do not consider the mainstem to have been occupied historically, and have not considered the Colorado River in our estimates of historical range. Early surveyors also variably used the term ''bonytail'' to describe roundtail chub (Valdez and

Ryel 1994, pp. 5–7), further clouding information on historical distribution, as some accounts of roundtail chub in the mainstem may have been bonytail (Gila elegans), which is a mainstem species in the Colorado River. Records from the mainstem Colorado River also may have been transients from nearby populations, such as some records from Grand Canyon, which may have been from the Little Colorado River (Voeltz 2002, p. 112). One record from between the two basins, a record of two roundtail chubs captured near Imperial Dam in 1973, illustrates this. Upon examining these specimens, Minckley (1979, p. 51) concluded that they were strays washed downstream from the Bill Williams River based on their heavily blotched coloration. This is a logical conclusion considering that roundtail chub from the Bill Williams River typically exhibit this blotched coloration (Rinne 1969, pp. 20–21; Rinne 1976, p. 78). Minckley (1979, p. 51), Minckley (1996, p. 75), and Mueller and Marsh (2002, p. 40) also considered roundtail chub rare or essentially absent in the Colorado River mainstem based on the paucity of records from numerous surveys of the Colorado River mainstem.

We conclude that historically, roundtail chub occurred in the Colorado River basin in two population centers, one each in the upper (largely in Utah and Colorado, and to a lesser extent, in Wyoming and New Mexico) and lower basins (Arizona and New Mexico), with apparently little, if any, mixing of the two populations. If there was one population, we would expect to find a large number of records in the mainstem Colorado River between the San Juan and Bill Williams Rivers, but very few records of roundtail chub exist from this reach of stream. Also, there is a substantial distance between these areas of roundtail chub occurrence in the two basins. The mouth of the Escalante River, which contains the southernmost population of roundtail chub in the upper basin, is approximately 275 river miles (mi) (443 kilometers (km)) upstream from Grand Falls on the Little Colorado River, the historical downstream limit of the most northern population of the lower Colorado River basin. The lower Colorado River basin roundtail chub population segment meets the element of discreteness because it was separate historically, and continues to be markedly separate today.

In more recent times, the upper and lower basin populations of the roundtail chub have been physically separated by Glen Canyon Dam, but that artificial separation is not the sole basis for our finding that the lower basin population is discrete from the upper basin. The historical information on collections suggests that there was limited contact even before the dam was built. Available molecular information for the species, although sparse, seems to support this; mitochondrial DNA markers (mtDNA; a type of genetic material) of roundtail chub in the Gila River basin are entirely absent from upper basin populations (Gerber *et al.* 2001, p. 2028; see Significance discussion below).

Significance

If we have determined that a vertebrate population segment is discrete under our DPS policy, we consider its biological and ecological significance to the taxon to which it belongs in light of Congressional guidance (see Senate Report 151, 96th Congress, 1st Session) that the authority to list DPSs be used ‘‘sparingly’’ while encouraging the conservation of genetic diversity. To evaluate whether a discrete vertebrate population may be significant to the taxon to which it belongs, we consider available scientific evidence of the discrete population segment’s importance to the taxon to which it belongs. Since precise circumstances are likely to vary considerably from case to case, the DPS policy does not describe all the classes of information that might be used in determining the biological and ecological importance of a discrete population. However, the DPS policy describes four possible classes of information that provide evidence of a population segment's biological and ecological importance to the taxon to which it belongs. This consideration may include, but is not limited to: (1) Persistence of the discrete population segment in an ecological setting that is unusual or unique for the taxon; (2) evidence that loss of the discrete population segment would result in a significant gap in the range of the taxon; (3) evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historical range; or (4) evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

Ecological Setting. Based on our review of the available information, we found that there are some differences in various ecoregion variables between the upper and lower Colorado River basins. For example, McNabb and Avers (1994) and Bailey (1995) delineated ecoregions and sections of the United States based on a combination of climate, vegetation, geology, and other factors. Populations of roundtail chub in the lower basin are primarily found in the Tonto Transition and Painted Desert Sections of the Colorado Plateau Semi-Desert Province in the Dry Domain, and the White Mountain-San Francisco Peaks- Mogollon Rim Section of the Arizona-New Mexico Mountains Semi-Desert- Open Woodland-Coniferous Forest Province Dry Domain. Populations of roundtail chub in the upper basin are primarily found in the Northern Canyonlands and Uinta Basin Sections of the Intermountain Semi-Desert and Desert Province in the Dry Domain, and the Tavaputs Plateau and Utah High Plateaus and Mountains Sections of the Nevada-Utah Mountains Semi-Desert- Coniferous Forest Province in the Dry Domain (McNabb and Avers 1994; Bailey 1995). These ecoregions display differences in hydrograph, sediment, substrate, nutrient flow, cover, water chemistry, and other habitat variables of roundtail chub. Also, there are differences in type, timing, and amount of precipitation between the two basins, with the upper basin (3–65 inches (in) per year (8–165 centimeters (cm) per year)) (Jeppson 1968, p. 1) somewhat less arid than the lower basin (5–25 in per year (13–64 cm per year)) (Green and Sellers 1964, pp. 8–11).

The type (snow or rain) and timing of precipitation are major factors determining the pattern of annual streamflow. A hydrograph depicts the amount of runoff or discharge over time (Leopold 1997, pp. 49–50). The hydrograph of a stream is a major factor in determining habitat characteristics and their variability over space and time. Habitats of roundtail chub in the lower basin have a monsoon hydrograph or a mixed monsoon-snowmelt hydrograph. A monsoon hydrograph results from distinctly bimodal annual precipitation, which creates large, abrupt, and highly variable flow events in late summer and large, longer, and less variable flow events in the winter (Burkham 1970, pp. B3–B7; Green and Sellers 1964, pp. 8–11; Minckley and Rinne 1991, p.12). Monsoon hydrographs are characterized by high variability, including rapid rise and fall of flow levels with flood peaks of one or more orders of magnitude greater than base, or ‘‘normal low’’ flow (Burkham 1970, pp. B3–B7; Ray et al. 2007, p. 1617).

In the upper basin, roundtail chub habitats have strong snowmelt hydrographs, with some summer, fall, and winter precipitation, but with the majority of major flow events in spring and early summer (Bailey 1995, p. 341; Carlson and Muth 1989, p. 222; Woodhouse *et al.* 2003, p.

1551). Snowmelt hydrographs are characterized by low variability; long, slow rises and falls in flow; and peak flow events that are less than an order of magnitude greater than the base flow. The lower basin has lower stream flows and warmer temperatures in late spring and early summer; in contrast, this is typically the wettest period in the upper basin (Carlson and Muth 1989, p. 222). Regarding the differences between the two basins, Carlson and Muth (1989), for example, conclude, ‘‘The upper basin produced most of the river’s discharge, and peak flows occurred after snowmelt in spring and early summer. Maximum runoff in the lower basin often followed winter rainstorms.’’ Sediment loads vary substantially between streams in both basins, but are generally lesser in the upper basin than the lower, and patterning of sediment movement differs substantially because of the different hydrographs. In general, roundtail chub habitat in the lower Colorado River basin is of lower gradient, smaller average substrate size, higher water temperatures, higher salinity, smaller base flows, higher flood peaks, lesser channel stability and higher erosion, and substantially different hydrographs than the habitat in the upper Colorado River basin. Measurable hydrographic differences between the two basins are evident, as are differences in landscape-level roundtail chub habitats between the upper and lower basins.

Gap in the Range. Roundtail chub in the lower Colorado River basin can be considered significant under our DPS analysis because loss of the lower Colorado River populations of roundtail chub would result in a significant gap in the range of the taxon; this area constitutes over one third of the species’ historical range (two out of six states), including the species’ entire current range in two states (Arizona and New Mexico) and all of several major river systems, including the Little Colorado, Bill Williams, and Gila River basins. Additionally there are 74 populations of roundtail chub remaining in the upper basin and 31 in the lower basin; thus, the lower basin populations also constitute approximately one third (30 percent) of the remaining populations of the species (Bezzerides and Bestgen 2002, pp. 28–29, Appendix C; Voeltz 2002, pp. 82–83). The populations in the lower basin also account for approximately 107,300 square mi (270,906 square km; 49 percent) of the 219,310 square mi (568,010 square km) of the Colorado River Basin (U.S. Geological Survey 2006, pp. 94–102). In addition, the roundtail chub historically occupied up to 2,796 mi (4,500 km) of stream in the lower basin and currently occupies between 497 mi (800 km) and 901 mi (1450 km) of stream habitat in the lower basin. These populations are not newly established, ephemeral, or migratory; the species has been well established in the lower Colorado River basin, and has represented a large portion of the species’ range for a long period of time (Bezzerides and Bestgen 2002, pp. 20–29; Voeltz 2002, pp. 82–83).

Whether the Population Represents the Only Surviving Natural Occurrence of the Taxon. As part of a determination of significance, our DPS policy suggests that we consider whether there is evidence that the population represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historical range. The roundtail chub in the lower Colorado River basin is not the only surviving natural occurrence of the species. Consequently, this factor is not applicable to our determination regarding significance.

Marked Differences in Genetic Characteristics. Long-standing difficulties in morphological discrimination and taxonomic distinction among members from the lower Colorado *G. robusta* complex, and the genus *Gila* as a whole, due in part to the role hybridization has played in its evolution, have plagued conservation efforts. But it is important to consider variation throughout the entire Colorado River basin to place variation and divergence in the lower basin Gila robusta complex in appropriate context. Two isolated species of hybrid origin (involving *G. robusta* with *G. elegans* and *G. cypha*) can be found in the Virgin and White River drainages (*G. seminuda*—DeMarais *et al*. 1992, p. 2747; *G. jordani*—Gerber *et al.* 2001, p. 2033, respectively). *G. robusta* is relatively abundant in the mainstem Colorado River and tributaries above the Glen Canyon Dam in the upper basin. All individuals from the headwaters of the Little Colorado River and the mainstem Colorado River and tributaries above Glen Canyon Dam in the upper basin possess *G. cypha* or *G. elegans* mtDNA (Dowling and DeMarais 1993, pp. 444–446; Gerber *et al*. 2001, p. 2028). However, populations of the *G. robusta* complex of the lower basin in the Bill Williams and Gila River basins (including *G. robusta*, *G. intermedia*, and *G. nigra*) possess a unique, divergent mtDNA lineage that has never been found outside the lower basin (Dowling and DeMarais 1993, pp. 444– 446; Gerber *et al*. 2001, p. 2028). But as Gerber *et al.* (2001, p. 2037) noted, genetic information in *Gila* poorly accounts for species morphology, stating ‘‘the decoupling of morphological and mtDNA variation in Colorado River *Gila* illustrates how hybridization and local adaptation can play important roles in evolution.’’ Although individuals in the Little Colorado River illustrate some minor genetic uniqueness, the evidence, though limited (samples size in Gerber *et al*. 2001 was limited to seven individuals) indicates these populations align more closely with the upper Colorado River basin populations. But discriminating between populations of *Gila* based on these data is difficult, and more data and analysis may help to place these populations in better perspective.

DPS Conclusion

We evaluated the lower Colorado River populations of the roundtail chub to determine whether they meet the definition of a DPS, addressing discreteness and significance as required by our policy. We considered the extent of the range of the roundtail chub in the lower Colorado River basin relative to the rest of the species' range, the ecological setting of roundtail chub in the lower Colorado River basin, and available information on the genetics of the species. We concluded that the lower Colorado River populations are discrete from the upper Colorado River basin populations on the basis of their present and historical geographic separation of 275 river mi (444 km) and because few historical records have been detected in the mainstem Colorado River between the two population centers that would confirm significant connectivity historically. We also concluded that the lower Colorado River basin roundtail chub is significant because of its unique ecological setting compared to the upper basin, and because the loss of the species from the lower basin would result in a significant gap in the range of the species. Genetic information for this species has long been difficult to interpret, and additional data and analysis may help to clarify this. The best available information demonstrated that these populations are discrete, persist in an ecological setting that is unique for the taxon, and, if lost, would result in a significant gap in the range of the taxon. Because this population segment meets both the discreteness and significance elements of our DPS policy, the lower Colorado River population segment of the roundtail chub qualifies as a DPS in accordance with our DPS policy, and as such, is a listable entity under the Act.

THREATS

A. <u>The present or threatened destruction, modification, or curtailment of its habitat or range</u>.

Roundtail chub has been eliminated from much of its historical range because many formerly occupied areas are now unsuitable due to dewatering, impoundment, channelization, and channel changes caused by alteration of riparian vegetation and watershed degradation (Miller 1961, pp. 367–371; Miller 1972, pp. 240, 242; Deacon *et al.* 1979, pp. 32, 34; Bestgen and Propst 1989, p. 409; Girmendonk and Young 1997, p. 16–44; Bezzerides and Bestgen 2002, pp. 6–9, 24–33; Voeltz 2002, pp. 87–89). In addition, areas where roundtail chub still occurs have been significantly altered or are currently being altered by the same and additional factors, including mining, improper livestock grazing, wood cutting, recreation, urban and suburban development, groundwater pumping, dewatering, dams and dam operation, contaminants, and other human actions (Minckley 1973, p. 101; Minckley 1985, pp. 12–15, 65–67; Bestgen and Propst 1989, p. 409; Bezzerides and Bestgen 2002, pp. 24–33; Tellman *et al.* 1997, pp. 159–170; Voeltz 2002, pp. 87–89; McKinnon 2006a, 2006b, 2006c, 2006d, 2006e). These activities and their effects on the roundtail chub are discussed in further detail below. It is important to recognize that in most areas where roundtail chub historically occurred or currently occur, two or more threats may be acting in combination in their influence on the roundtail chub or on suitability of habitat to support the species (Voeltz 2002, pp. 23–81; Cantrell 2009, p. 15).

The modification and destruction of aquatic and riparian communities in the post-settlement arid southwestern United States from anthropogenic (human-caused) land uses is well documented (Miller 1961, pp. 367–371; Sullivan and Richardson 1993, pp. 35– 42; Girmendonk and Young 1997, pp. 45–52; Tellman *et al.* 1997; Webb and Leake 2005, pp. 305–310; Ouren *et al.* 2007, pp. 16–22). Significant loss of habitat and species range has also been well documented (Miller 1961, p. 365; Minckley 1985, pp. 4–15; Minckley and Deacon 1991, pp. 7–18), and has been reported specifically for the roundtail chub in the lower Colorado River basin (Voeltz 2002). An estimated one-third of Arizona's pre-settlement wetlands have dried or have been rendered ecologically dysfunctional (Yuhas 1996). Although many of these habitat changes, and the greatest loss and degradation of riparian and aquatic communities in Arizona, occurred during the period from 1850 to 1940, (Miller 1961, pp. 365–371; Minckley 1985, pp. 4–15; Webb and Leake 2005, pp. 305–310), many of these land activities continue today and are discussed in detail below.

Dams, Diversions, and Groundwater Withdrawal

Major dams have been constructed throughout the historical and current range of the roundtail chub in the lower Colorado River basin, including four dams on the Gila River, four on the Salt River, and two on the Verde River, and have been a substantial cause in the decline of the species (Minckley 1985, pp. 12–14; Tellman *et al.* 1997, pp. 159– 170; Voeltz 2002, pp. 19–22, 44–45). Although roundtail chubs survive, reproduce, and can even be cultured in small ponds, they do not appear to be able to persist in reservoirs. Much of the lower Salt River and portions of the lower Verde River are now reservoirs where roundtail chub formerly occurred (Voeltz 2002, pp. 20, 84–85). In addition to the loss of flowing river habitats through inundation, dams also modify sediment dynamics, timing and magnitude of downstream flow, and temperature characteristics of habitats (Gloss *et al.* 2005, pp. 17–32, 69–85). Such changes can negatively affect the distribution and survival of warm-water adapted native fishes like roundtail chub.

Tailwaters of large dams are often too cold for successful reproduction by native warmwater fishes. Cooler water temperatures can also reduce the growth rates and survival of embryos and juvenile warm-water fish. Larvae grow more slowly, which increases their risk of predation and decreases accumulation of energetic reserves needed for overwinter survival. Cold water temperatures may slow growth and reduce reproductive success (Marsh 1985, p. 129; Valdez and Ryel 1994, pp. 4–16; Muth *et al.* 2000, pp. 5–1–5–39). Reservoirs also capture sediment and discharge sediment-poor water downstream that alters channel characteristics (Collier *et al.* 1996, pp. 63–85; Gloss *et al.* 2005, pp. 17–32; Wright *et al.* 2008, p. 4). Alteration of the magnitude and timing of flow and capture of sediment in reservoirs can increase water clarity and channel scour downstream from the dam (Collier *et al.* 1996, pp. 63–85). Changes in discharge timing and magnitude may shift environmental cues needed by fish for proper timing of migration and spawning, thereby preventing successful reproduction (Muth *et al*. 2000, pp. 5–1–5–39). Dams also prevent upstream, and to a lesser degree downstream, movement of all age classes to historical spawning, rearing, and overwintering habitat (Martinez *et al.* 1994, pp. 227–239; Schuman 1995, pp. 249–261).

Within the range of roundtail chub in the lower Colorado River basin, water for human uses is supplied by reservoirs created by dams, surface water diversions, and groundwater pumping. The hydrologic connection between groundwater and surface flow of intermittent and perennial streams is becoming better understood. Groundwater pumping creates a cone of depression within the affected aquifer that slowly radiates outward from the well site. When the cone of depression intersects the hyporheic zone of a stream (the active transition zone between surface water and groundwater that contributes water to the stream itself), the surface water flow may decrease. Continued groundwater pumping can draw down the aquifer sufficiently to create a water-level gradient away from the stream and floodplain (Webb and Leake 2005, p. 309). Finally, complete disconnection of the aquifer and the stream results in dewatering of the stream (Webb and Leake 2005, p. 309).

Roundtail chub has been eliminated from much of its historical range because many formerly occupied areas are now unsuitable due to dewatering (Miller 1961, pp. 367–371; Miller 1972, pp. 240, 242; Deacon *et al.* 1979, pp. 32, 34; Bestgen and Propst 1989, p. 409; Girmendonk and Young 1997, pp. 16– 44; Bezzerides and Bestgen 2002, pp. 6– 9, 24–33; Voeltz 2002, pp. 87–89). Dams, diversions, and groundwater pumping have effectively eliminated much of the riverine habitat in Arizona that roundtail chub once occupied simply by eliminating downstream flow and drying much of the historical river courses (Tellman et al. 1997, pp. 164, 169; Voeltz 2002, pp. 19–22, 44–45). In 1904, Chamberlin noted that a primary cause of fish extinctions in the lower Colorado River basin was irrigation operations including water use, preclusion of migration due to dams, and destruction of fish in ditches (Minckley 1999, p. 215). Groundwater pumping and water diversions continue to pose a significant threat to the continued existence of the roundtail chub by reducing the quantity and quality of habitat (Girmendonk and Young 1997, p. 56), and by altering streamflow and reducing the frequency and magnitude of floods. Diversions also impact fish populations by creating barriers to fish movement and by entraining drifting larvae and fish into irrigation canals where they may later perish (Martinez *et al.* 1994, pp. 227– 239). Chamberlin found that all of the flow of the San Pedro River was diverted at two dams near Fairbanks in 1904 (Minckley 1999, pp. 200–201). Reaches of the Verde River near Tapco and the urban areas in the Verde Valley contain numerous, significant diversion dams, and dead fishes have been reported in surrounding pastures following irrigation (Girmendonk and Young 1997, p. 56). Roundtail chubs are also diverted from the lower Salt River into canals in the Phoenix area, where they likely perish as a result of annual dewatering for canal maintenance, although some fish are salvaged and returned to the Salt River.

The Service found that, in lotic systems (flowing water), roundtail chub habitat is essentially eliminated when flow consistently drops below 10 cubic feet per second (0.3 cubic meters per second) (Service 1989, pp. 32–33). In the Verde River, the lowered water level during the summer irrigation season alters physical characteristics of the river, changing stream width and depth (Girmendonk and Young 1997, p. 55– 56), with much of the stream in the summer dry season reduced to isolated pools, especially in the urbanized Verde Valley area. The upper Gila River, in the vicinities of Cliff, Redrock, and Virden, New Mexico, has been entirely dewatered on occasion by diversions for agriculture (Bestgen 1985, p. 13). Water withdrawal alters stream flow regime, in part by reducing flooding (Brouder 2001, p. 302; Freeman 2005, p. 1). Brouder (2001, p. 302) hypothesized that periodic flooding in the Verde River is needed to maintain roundtail chub habitat, and further that reductions in periodic flooding due to continued water withdrawal and extended drought could lead to roundtail chub recruitment failure and significant population declines.

To accommodate the needs of rapidly growing rural and urban populations (see the ‘‘Urban and Rural Development’’ section), surface water is commonly diverted to serve many industrial and municipal uses. These water diversions have dewatered large reaches of once perennial or intermittent streams, adversely affecting roundtail chub habitat throughout its range in Arizona and New Mexico. Many tributaries of the Verde River are permanently or seasonally dewatered by water diversions for agriculture (Paradzick *et al.* 2006, pp. 104–110). Water withdrawal (dams, diversions, and groundwater pumping) is a threat to most extant populations of roundtail chub in the lower Colorado River basin (Bestgen and Propst 1989, p. 409; Girmendonk and Young 1997, p. 56; Propst 1999, p. 25; Voeltz 2002, pp. 23– 81; Cantrell 2009, p. 15). Increased urbanization and population growth results in an increase in the demand for water and, therefore, water development projects. Municipal water use in central Arizona has increased by 39 percent in the last 8 years (American Rivers 2006, pp. 2–3). Areas of the Verde River basin continue to experience explosive population growth and concomitant demand for water. Traditionally rural portions of Arizona are also predicted to experience significant growth. The populations of developing cities and towns of the Verde watershed are expected to more than double in the next 50 years, which may pose exceptional threats to riparian and aquatic communities of the Verde Valley (Girmendonk and Young 1993, p. 47; American Rivers 2006; Paradzick *et al.* 2006, p. 89). Communities in Yavapai and Gila counties such as the Prescott-Chino Valley and the City of Payson have seen rapid population growth in recent years. For example, the population in the town of Chino Valley, at the headwaters of the Verde River, grew by 22 percent between 2000 and 2004; Gila County, which includes reaches of Tonto Creek and the Salt, White, and Black Rivers, grew by 20 percent between 2000 and 2003 (U.S. Census Bureau 2005). Voeltz (2002, p. 35) also considered groundwater pumping from new development a serious threat for all streams of the Burro Creek drainage in the Bill Williams River basin.

In the Verde River basin, water demands of increasing population density and associated development have reduced the flow of the Verde River, and seem likely to continue to do so. A number of researchers have reported that groundwater in the Big Chino aquifer is connected to the Verde River and that groundwater pumping of this aquifer affects stream flow in the mainstem Verde River (Wirt and Hjalmarson 2000, pp. 44–47; Ford 2002, p. 1; Woodhouse *et al.* 2002, pp. 1–4). The relationship between groundwater pumping in the lower Big Chino aquifer and Verde River flow has been apparent since at least the early 1960s when a surge of pumping due to new development caused Verde River flows to drop significantly (Wirt and Hjalmarson 2000, p. 27). The Big Chino aquifer is estimated to supply approximately 80 percent of the base flow of the Upper Verde River (Wirt and Hjalmarson 2000, p. 44, Wirt *et al.* 2004, p. G7; Blasch et al. 2006, updated 2007, pp. 1–2). Woodhouse et al. (2004, pp. 1–4) also reported that numerous groundwater wells throughout the upper Verde River watershed have reduced the water table of the Verde River (Woodhouse et al. 2002, pp. 1–4). A proposed water project in the area, the Big Chino Water Ranch Project, will include infrastructure to pump groundwater in the Chino Valley and pipe it to nearby communities. It will include a 30 mi (48 km), 36 in. (91 cm) diameter pipeline that will deliver up to 2.8 billion gallons (gal) (12,400 acre-feet (ac-ft)) of groundwater annually from the Big Chino sub-basin aquifer to the rapidly growing area of Prescott Valley for municipal use (McKinnon 2006c; Davis 2007, pp. 1–2). This potential reduction or loss of baseflow in the Verde River could seasonally dry up large reaches of the stream.

Roundtail chub habitat in Clear Creek and Chevelon Creek in the Little Colorado River watershed appears severely threatened by dewatering. Recent studies and assessments of the Little Colorado River watershed and its underlying groundwater resources indicate that these water resources are under increasing pressure from development (Bills *et al.* 2005). The North Central Arizona Water Supply Study Report of Findings (U.S. Bureau of Reclamation 2006) predicts that by the year 2050, the human demand for water will not be met in north-central Arizona. Plans are underway to determine how additional water resources can be developed to provide for this unmet demand. Protecting water resources for environmental needs is included in these plans. However, it is likely that, with the need for additional demand and use of water for human uses, there will be additional stress on these aquatic ecosystems. In addition, there is high potential that extended drought, perhaps exacerbated through global climate change (see the ‘‘Climate Change’’ section below), will further stress water resources. Two hydrologic models developed to evaluate the impacts of additional pumping on groundwater in the C-aquifer in Arizona support these findings. The C-aquifer is located on the Colorado Plateau of northeastern Arizona, western New Mexico, and southern Colorado and is the aquifer that underlies the lower Colorado River Basin. Two groundwater models, one developed by the U.S. Geological Survey (Leake *et al*. 2005), and a second full-flow groundwater model developed to evaluate cumulative effects to surface water flow (Papadopulos and Associates 2005), have been developed for the area encompassing the C-aquifer. Both models predicted depletion in baseflow from current and proposed groundwater withdrawals in lower Chevelon and Clear Creeks over the next 50 to 100 years. The flow model (Papadopulos and Associates 2005) predicted that, based on current regional pumping, the base flow of lower Chevelon Creek would be zero in 60 years.

Water use from rapidly growing communities and agricultural and mining interests have altered flows or dewatered significant reaches during the spring and summer months in some of the Verde River’s larger, formerly perennial tributaries such as Wet Beaver Creek, West Clear

Creek, and the East Verde River (Girmendonk and Young 1993, pp. 45–47; Sullivan and Richardson 1993, pp. 38–39; Paradzick *et al.* 2006, pp. 104–110). The upper Gila River is also threatened by water diversions and water allocations. In New Mexico, a water settlement in 2004 allows New Mexico the right to withhold 4.5 billion gal (13,800 ac-ft) of surface water every year from the Gila and San Francisco rivers (McKinnon 2006d). Project details are still under development, so the impact of this project on aquatic resources cannot yet be evaluated.

The Arizona Department of Water Resources manages water supplies in Arizona and has established five Active Management Areas across the State (Arizona Department of Water Resources 2006). An Active Management Area is established by the Arizona Department of Water Resources when an area's water demand has exceeded the groundwater supply and an overdraft has occurred. In these areas, groundwater use has exceeded the rate that precipitation can recharge the aquifer. Geographically, all five Active Management Areas overlap the historical distribution of the roundtail chub in Arizona. The declaration of these Active Management Areas further illustrates the current and future threats to aquatic habitat in these areas and is a cause of concern for the long-term maintenance of historical and occupied roundtail chub habitat. Such overdrafts reduce surface water flow of streams that are hydrologically connected to the aquifer under stress, and this stress can be further exacerbated by the surface water diversions.

Livestock Grazing

Historical accounts of livestock grazing and its effects in Arizona are consistent: widespread overgrazing throughout the State in the mid- to late- 1880s denuded rangelands and so altered watersheds that the landscape was changed forever. In fact, in 1906, F.M. Chamberlain conjectured that the alteration of landscapes was so profound that it had actually resulted in climate change to a more arid climate in the region (as cited in Minckley 1999). Similarly, Croxen (1926) describes changes to the Tonto National Forest resulting from poorly managed livestock grazing as largely running their course by the late 1880s. Between 1880 and 1890, the widespread improper grazing regimes that had denuded the landscape for 10 to 20 years or so throughout the state was followed by severe flooding. The end result was a rapid transition for many aquatic habitats from permanent, meandering streams to intermittent ''flashy'' arroyos (intermittent streams with higher peak flows and lower base flows) (Minckley and Hendrickson 1984, pp. 131–132; Cheney *et al.* 1990, pp. 5, 10).

Poorly managed livestock grazing has damaged approximately 80 percent of stream, cienega (marsh), and riparian ecosystems in the western United States (Kauffman and Krueger 1984, pp. 433– 435; Weltz and Wood 1986, pp. 367– 368; Waters 1995, pp. 22–24; Pearce *et al.* 1998, p. 307; Belsky *et al.* 1999, p. 1) and severely altered many of the habitats formerly and currently occupied by roundtail chub. Livestock grazing today is much more strictly managed by Federal agencies and Tribes because the effects of grazing and mismanagement are now better understood and have been well documented. For example, Stromberg and Chew (2002, p. 198) and Trimble and Mendel (1995, p. 243) discuss the propensity for poorly managed cattle to remain within or adjacent to riparian communities, a behavior that is more pronounced in arid regions (Trimble and Mendel 1995, p. 243). In one rangeland study, it was concluded that 81 percent of the vegetation that was consumed, trampled, or otherwise removed was from a riparian area, which amounted to only 2 percent of the total grazing space (Trimble and Mendel 1995, p. 243). Additionally, grazing rates can be 5 to 30 times higher in riparian areas (Trimble and Mendel 1995, p. 244). But as a direct result of this research, management agencies now exclude livestock grazing from many riparian areas and streams, or only permit light and seasonal grazing in these areas. We summarize here the effects of livestock grazing, but it is important to note that these effects only become tangible if livestock grazing is poorly managed. If properly managed, there is some evidence that affects to wildlife habitat can be positive. In this respect, livestock grazing is largely a threat of the past, and if properly managed, is not likely a threat. Although more research is needed, livestock grazing strategies can be developed that are compatible and even complementary with fisheries management (Platts 1989, p. 103; Vavra 2005, p. 128). The American Fisheries Society Policy Statement on livestock grazing concludes that ‘‘it is our strong contention that when properly implemented and supervised, grazing could become an important management tool benefiting fish and wildlife riparian habitats’’ (American Fisheries Society 2009).

Livestock grazing occurs throughout the range of roundtail chub in the lower Colorado River basin in all drainages in which the species occurs (Tellman *et al.* 1997, p. 167; Propst 1999, p. 25; Voeltz 2002, pp. 23–88), and has resulted in the degradation of roundtail chub habitat from a number of mechanisms. Livestock directly affect roundtail chub habitat through removal of riparian vegetation (Clary and Webster 1989, p. 1; Clary and Medin 1990, p. 1; Schulz and Leininger 1990, p. 295; Armour *et al.* 1991, pp. 8–10; Fleishner 1994, pp. 630–631), which can result in reduced bank stability, fewer pools, and higher water temperatures (Kauffman and Krueger 1984, p. 432; Minckley and Rinne 1985, p. 150; Schulz and Leininger 1990, p. 295; Fleishner 1994, pp. 630–631; Belsky et al. 1999, pp. 8– 12). Livestock grazing can also cause increased sediment in the stream channel, due to streambank trampling and riparian vegetation loss (Weltz and Wood 1986, pp. 367–368; Waters 1995, pp. 22–24; Pearce et al. 1998, p. 307). Livestock physically alter streambanks through trampling and shearing, leading to bank erosion (Trimble and Mendel 1995, p. 244; Clary and Webster 1989, pp. 7–8). In combination, loss of riparian vegetation and bank erosion can alter channel morphology, including increased erosion and deposition, downcutting, and an increased width/depth ratio, all of which can lead to a loss of pool habitats and loss of shallow side and backwater habitats (Trimble and Mendel 1995, pp. 243–250; Belsky *et al.* 1999, pp. 1–2). Pool habitats are required by the roundtail chub, and shallow side and backwater habitats are used by larval chubs for sheltering from larger bodied predators and for feeding (Minckley 1973, p. 100; Brouder *et al.* 2000, pp. 6– 7; Minckley and DeMarais 2000, p. 255).

Although livestock grazing is unlikely to be a threat if properly managed, physical developments necessary to support livestock grazing can also have direct effects on roundtail chub. Water sources are essential to livestock operations, and numerous stock tanks, stream diversions, and various types of groundwater pumps are utilized to provide water for livestock (Valentine 1989, pp. 413–431). This diverts water from natural surface waters, including streams supporting roundtail chub (see ‘‘Dams, Diversions, and Groundwater Withdrawal’’ section above). In addition to livestock developments, thousands of miles of fencing are needed to partition cattle into pastures or rotation-type grazing systems (Valentine 1989, pp. 435–449). Maintaining this infrastructure requires a substantial network of roads. Road use and maintenance have been a major factor in altering the morphology and habitat of streams in the Southwest (see ‘‘Road

Construction, Use, and Maintenance'' section below).

Livestock can indirectly impact aquatic and riparian habitats at a watershed level though soil compaction, altered soil chemistry, and reductions in upland vegetation cover; these changes lead to an increased severity of floods and sediment loading, lower water tables, and altered channel morphology (Rich and Reynolds 1963, p. 222; Orodho et al. 1990, p. 9; Schlesinger *et al*. 1990, p. 1043; Belsky *et al.* 1999, p. 1). One consequence of these changes in watershed function is a reduction in the quantity and quality of pool habitat. Lowered water tables result in the direct loss of pool habitats, simply because water is not available to form pools. Increased erosion and sedimentation results in filling of pools with sediments. Channel incision and increased flood severity eliminate pools through bed scour, and reduce habitat complexity by creating shallow, uniform streambeds (see Trimble and Mendel1995, pp. 245–251; Belsky *et al.* 1999, pp. 25–35). Much of Arizona's rivers and streams were modified by livestock grazing in this way by the mid 1900s (Miller 1961, pp. 394–395; Minckley 1999, p. 215), and the effects to aquatic habitat from that historical modification remain today.

Livestock use has been shown to alter the composition and community structure of the aquatic fauna (regional animal life), which can also indirectly impact roundtail chub by reducing the quantity and quality of food sources. Altered stream channel characteristics, sediment deposition, changes in substrate size, and nutrient cycle changes are all potential effects of livestock grazing that can alter aquatic invertebrate communities (Li *et al.* 1994, pp. 638–639; Hoorman and McCutcheon 2005, p. 3), resulting in changes to the food base for aquatic vertebrates, particularly fish. Few detailed studies of changes in aquatic faunal communities have been completed on streams in the range of the roundtail chub, but given the widespread occurrence of ongoing and historical livestock grazing, changes in aquatic faunal community has likely occurred in many streams within historical range of roundtail chub.

Livestock grazing results in loss of aquatic habitat complexity, thus reducing diversity of habitat types available and altering fish communities (Li et al. 1987, pp. 627, 638–639). In the arid west, loss of habitat complexity has been a major contributing factor in declines of native fishes and amphibians and in the displacement of native fish species by nonnative species (Bestgen and Propst 1986, p. 209; Minckley and Rinne 1991, pp. 2–5; Baltz and Moyle 1993, p. 246; Lawler *et al.* 1999, p. 621). Livestock grazing has also contributed significantly to the introduction and spread of nonnative aquatic species through the proliferation of stock tanks (manmade ponds that are water sources for livestock) which serve as created habitat for nonnative species (Rosen *et al.* 2001, p. 24; Hedwall and Sponholtz 2005, pp. 1–5; Service 2008, pp. 46–51). The spread of nonnative species is a threat to roundtail chub because these nonnative species prey on and compete with roundtail chub (see ''Nonnative Species'' section below for more discussion). Another direct effect of livestock grazing in intermittent aquatic habitats is the potential for livestock to drink occupied roundtail chub habitat dry under certain conditions, completely eliminating all habitat and killing any roundtail chub present. Vallentine (1989, pp. 413–431) states that cattle need an average of 12 to 15 gallon (gal) (45 to 57 liters (L)) of water per day per animal, and that this varies seasonally because of the moisture content of forage, ambient temperature and humidity, and other factors. Griffith (1999, p. 1) states that at 50 °F (10 °C), a cow may consume about 5 to 7 gal (19 to 26 L) per day, but the amount increases by 0.4 gal (1.5 L) per day for every one-degree increase in air temperature; thus at 95 °F (35 °C) the same cow will drink an average of 24 gal (91 L) per day. Roundtail chub can be limited to small isolated pool habitats during the driest times of the year that can be as little as several hundred gal (1–2000 L) in volume, and have flow so low that inflow is essentially equal to or less than evaporation; several cows could completely dry such habitats in a matter of days, especially in times of drought. Gila chub, a related species, and its habitat, is believed to have been eliminated in this manner from portions of Indian Creek in 2002–2003 (Service 2006, p. 10).

Livestock grazing also contributed to shrub invasion of grasslands (Brown and Archer 1999, p. 2385). Shrub invasions decrease biodiversity and create ecosystem instability in desert ecosystems (Baez and Collins 2008). Shrub invasion also can lead to a greater amount of water loss through plants, which contributes to desertification (Knapp et al. 2008, p. 621). Fire regimes are also altered by shrub invasion (Richburg et al. 2001, p. 104), and altered fire regimes pose a threat to roundtail chub due to the effects of wildfire on watersheds and direct effects of ash and sediment flows following wildfires (see ‘‘High-Intensity Wildfires’’ section below).
All extant populations of roundtail chub are subject to some level of livestock grazing in the watershed, but specific problems associated with livestock grazing have only been noted in four streams (Chevelon, East Clear, Burro, and Salome Creeks) (Voeltz 2002; Cantrell 2009, p. 15). In Chevelon Creek, Arizona Department of Environmental Quality water quality standards for sediment and turbidity (muddiness of water) were not met due to grazing and high channel erosion, habitat modification, and unsatisfactory watershed condition for the watershed (Voeltz 2002, p. 27). In the Verde River, Girmendonk and Young (1997, p. 53) noted cattle grazing had a major impact on both upland and aquatic communities due to trampled banks and heavily grazed vegetation from Sullivan Lake downstream to Cottonwood. However, we note that in most streams currently occupied by roundtail chub, grazing has been removed from the riparian area. For example, livestock grazing has since been removed from that portion of the Verde River discussed by Girmendonk and Young (1997).

The above discussion illustrates that poorly managed livestock grazing can adversely affect roundtail chub in several ways, from direct loss due to livestock water and vegetation consumption and trampling, to indirect habitat alteration from changes in the watershed. In general, properly managed livestock grazing utilizes rest-rotation grazing systems that exclude riparian areas or limit their use to the winter season, and utilize monitoring systems to ensure that use of uplands and riparian areas are not overgrazed. When livestock grazing is well managed in this manner it is not likely a threat to the roundtail chub. The capability exists to create livestock grazing strategies that are compatible and even complementary to maintaining fisheries habitat, although more research is needed in this regard (Platts 1989, p. 103; Vavra 2005, p. 128).

Urban and Rural Development

Urban and rural development is considered a threat in every stream currently occupied by roundtail chub (Cantrell 2009, p. 18). Development can affect roundtail chub and its habitat through direct alteration of streambanks and floodplains from construction of homes and businesses, as well as from numerous related impacts. Tellman *et al.* (1997, pp. 92–93) listed the following impacts to rivers in Arizona from urban and rural development: increased use of floodplain for homes and businesses, sand and gravel mining in the floodplain for construction materials, pollution from trash and wastewater in river bed, depletion of water supplies, increased land covered by impervious surfaces with greater surface runoff and less infiltration, building of flood control structures, and increased recreational impacts. On a broader scale, development alters the watershed with consequent changes in the hydrology, sediment regimes, and pollution input (Leopold 1997, pp. 97–102; Horak 1989, p. 42; Medina 1990, p. 351; Reid 1993, pp. 48–51; Waters 1995, pp. 42–44; Wheeler *et al.* 2005, p. 141).

Development changes watersheds from land surfaces where precipitation can infiltrate the soil and reach a stream slowly as subsurface flow, to one with impervious surfaces such as rooftops, asphalt, and compacted soils (Schueler 1994, p. 100; 1995, p. 233; Wheeler *et al.* 2005, p. 151). These impervious surfaces capture precipitation and route it quickly and directly into gutters, storm drains, overland flow, and streams (Hollis 1975, p. 431; Wheeler *et al.* 2005, p. 151). Similarly, precipitation falling on impervious surfaces without direct hydraulic connections to streams may reach streams quickly as overland flow (Horton 1945, p. 275; Leopold 1973, p. 1845; Wheeler *et al*. 2005, p. 151). Thus, urbanization fundamentally alters the delivery of water to streams (Environmental Protection Agency 2008, p. 1). These changes in precipitation delivery alter stream flow regimes. Peak flow volume from precipitation events increases (Hollis 1975, p. 431; Neller 1988, p. 1; Booth 1990, pp. 407–417; Clark and Wilcock 2000, p. 1763; Rose and Peters 2001, p. 246; Wheeler *et al.* 2005, p. 151). These changes increase the frequency and magnitude of floods (Hollis 1975, p. 431; Wheeler et al. 2005, p. 151), which cause a stream to increase its channel capacity by eroding its banks, downcutting its channel, or both (Hammer 1972, p. 1530; Leopold 1973, p. 1845; Booth 1990, p. 1752; Pizzuto *et al.* 2000, p. 79; Brown and Caraco 2001, pp. 16–19; Wheeler *et al.* 2005, p. 151). Because natural surfaces in a watershed transmit water slowly to the stream as subsurface flow, base flow in a stream is often from subsurface flow and groundwater that steadily contributes flow between precipitation events. The impervious surfaces caused by development alter this process, preventing precipitation from infiltrating, and resulting in a reduction in base flow of the stream (Simmons and Reynolds 1982, p. 1752; Wang *et al.* 2001, p. 255; 2003, p. 825; Wheeler *et al.* 2005, p. 151). Development within and adjacent to riparian areas has proven to be a significant threat to riparian and aquatic biological communities (Medina 1990, p. 351), with even low levels of development causing adverse impacts within a watershed (Wheeler *et al.* 2005, p. 142). Development can alter the nature of stream flow dramatically, changing streams from perennial to ephemeral, which can have direct consequences to stream fauna (Medina 1990, pp. 358– 359). Medina (1990, pp. 358–359) found that development reduced vegetation in streams and changed flow regimes, which resulted in a decrease in abundance of fish.

Development in and near stream courses usually results in removal of riparian vegetation, which leads to a number of changes to streams (Wheeler *et al.* 2005, p. 151). Riparian vegetation stabilizes streambanks and reduces bank erosion (Beeson and Doyle 1995, p. 983; Wynn and Mostaghimi 2006, p. 400), and helps moderate urban stream temperatures (LeBlanc *et al.* 1997, p. 445). Because riparian vegetation contributes leaves, wood, organic debris, and terrestrial invertebrates to streams, vegetation removal can often drastically alter food webs in streams (Vannote *et al.* 1980, p. 130; Hawkins and Sedell 1981, p. 387; Reid 1993, p. 74). Also, large woody debris can be an important component of stream channels because the debris stabilizes stream banks (Keller and Swanson 1979, p. 361), creates pools (Keller and Swanson 1979, p. 361; Rinne and Minckley 1985, p. 150), and provides habitat for macroinvertebrates (Benke et al. 1985, pp. 8–13; Rinne and Minckley 1985, p. 150) and fishes (Angermeier and Karr 1984, p.

716; Flebbe and Dolloff 1995, p. 579). Riparian vegetation also moderates stream temperatures (LeBlanc *et al.* 1997, p. 445). In small and medium-sized streams, riparian vegetation shades and cools the stream; loss of riparian vegetation contributes to warming of the stream (Barton *et al.* 1985, p. 365; LeBlanc *et al*. 1997, p. 445). Wang *et al.* (2003, p. 825) found that the maximum daily water temperature of streams in urbanized settings in Wisconsin and Minnesota increased by 0.5 °F (0.25 °C) with every 1 percent increase in the impervious area of the watershed.

Urban streams enlarge their channels by eroding their banks; this erosion, together with runoff from urban construction activities, adds fine sediment to the stream (Waters 1995, p. 43; Trimble 1997, p. 1442; Wheeler *et al.* 2005, p. 151), increasing turbidity, which can alter stream habitat productivity, adversely affect the food base for fish, eliminate rearing habitats, and fill in pool habitat (Waters 1995, p. 43). Because urbanization typically results in loss of riparian vegetation as areas near streams are cleared, riparian areas can lose the natural ability to absorb and filter out metals, fine sediment, and nutrients from overland runoff (McNaught *et al.* 2003, p. 7). Development can affect water quality in a number of ways. Urban runoff contains a variety of chemical pollutants including petroleum, metals, and nutrients from a variety of sources such as automobiles and building materials (Wheeler *et al.* 2005, p. 153). Some pollutants contain the nutrients nitrogen and phosphorus, which can cause a body of water to become nutrientenriched and stimulate the growth of aquatic plant life resulting in the depletion of dissolved oxygen. This can adversely affect fish by reducing dissolved oxygen to lethal levels (Hassler 1947, pp. 383–384; Cantrell 2009, p. 15). Development also leads to increases in the number of dumps and landfills that leach contaminants into ground and surface water, reducing water quality and thereby degrading roundtail chub habitat. Similarly, wastewater treatment plants that accompany development also can contaminate ground and surface water (Winter *et al.* 1998, p. 66). Pharmaceuticals and personal care products also may contain hormones, which are present in wastewater, and can have significant adverse effects to fishes, particularly fish reproduction (Kime 1995, p. 52; Rosen *et al.* 2007, pp. 1–4). The use of pesticides is also a source of water quality contamination from agricultural and residential use, which can have lethal and sublethal effects to fish (Ongley 1996). The use of pesticides occurs adjacent to nine populations of roundtail chub in Arizona (Cantrell 2009, p. 12).

The physical and chemical alterations of stream systems due to urbanization cause significant changes to the stream biological community (Wheeler *et al.* 2005, p. 153). Urbanized streams have fewer numbers and species of macroinvertebrates (Richards and Host 1994, p. 195; Kemp and Spotila 1997, p. 55; Kennen 1998, p. 3), and exhibit reduced biological health (Kennen 1998, p. 3). Urban streams also have lower overall abundance and diversity of fishes (Tramer and Rogers 1973, p. 366; Scott et al. 1986, p. 555; Medina 1990, p. 351; Weaver and Garman 1994, p. 162; Wang *et al.* 2000, p. 255; 2003, p. 825). Little is known about how urban development and the corresponding physical and chemical changes in streams result in changes in the stream ecosystem, although the physical changes appear more important in this process than the chemical changes (Wheeler *et al.* 2005, p. 154).

The net result of urbanization for roundtail chub is a decrease in habitat suitability, most significantly through a reduction in stream flow, although also through an increase in the probability of the presence of nonnative aquatic species that prey on and compete with roundtail chub (see ‘‘Nonnative Species’’ section below). As described above, development typically involves increased water use in the form of diversions of water from both surface flows and connected groundwater (Glennon 1995, pp. 133–139). The physical changes associated with development also result in a more ‘‘flashy’’ system, as described above, where runoff from precipitation rapidly exits the watershed, increasing flood flows, and decreasing base flow. These hydrologic changes can lead to streams changing from perennial to intermittent, and result in a corresponding decrease in fish abundance (Medina 1990, p. 351).

The effects of urban and rural development are expected to increase as human populations increase. Development has continually been increasing in the southwestern United States. Arizona increased its population by 394 percent from 1960 to 2000, and is second only to Nevada as the fastest growing state in terms of human population (Social Science Data Analysis Network 2000, p. 1). Growth rates in Arizona counties with historical or extant roundtail chub populations are also significant and increasing: Maricopa (463 percent); Cochise (214 percent); Yavapai (579 percent); Gila (199 percent); Graham (238 percent); Apache (228 percent); Navajo (257 percent); Yuma (346 percent); La Paz (142 percent); and Mohave (1,904 percent) (Social Science Data Analysis Network 2000). Population growth trends in Arizona are expected to continue into the future. The Phoenix metropolitan area, founded in part due to its location near the junction of the Salt and Gila Rivers, is a population center of 3.6 million people. The Phoenix metropolitan area is the sixth largest in the United States and is located in the fastest growing county in the United States since the 2000 census (McKinnon 2006a). Traditionally rural portions of Arizona are also predicted to see huge increases in human population. Developing cities and towns of the Verde watershed are expected to more than double in the next 50 years, which, as described above, is expected to threaten riparian and aquatic communities of the Verde Valley where roundtail chubs occur (Girmendonk and Young 1993, p. 47; American Rivers 2006; Paradzick *et al*. 2006, p. 89). Chino Valley, at the headwaters of the Verde River, grew by 22 percent between 2000 and 2004. Gila County, which includes reaches of Tonto Creek and the Salt, White, and Black rivers, grew by 20 percent between 2000 and 2003 (U.S. Census Bureau 2005). In New Mexico, a water settlement in 2004 allows New Mexico the right to withhold 4.5 billion gal (13,800 ac-ft) of surface water every year from the Gila and San Francisco rivers (McKinnon 2006d). Project details are still under development, so the impact of this project on aquatic resources has not yet been evaluated; however, the project represents another potential withdrawal of water from occupied habitat.

Given the arid nature of the Southwest, the predictions of further growth in an already large population center, and the adverse impacts to aquatic habitats that are associated with development, development will continue to be a threat to the roundtail chub. Urban and rural development is considered a threat in every stream currently occupied by roundtail chub (Cantrell 2009, p. 15).

Road Construction, Use, and Maintenance

Roads are a threat to roundtail chub and its habitat due to a variety of factors including fragmentation, modification, and destruction of habitat; increase in genetic isolation; facilitation of the spread of nonnative species via human vectors; increases in recreational access and the likelihood of subsequent, decentralized urbanization; and contributions of contaminants to aquatic communities (Burns 1972, p. 1; Barrett *et al.* 1992, p. 437; Eaglin and Hubert 1993, p. 884; Warren and Pardew 1998, p. 637; Waters 1995, p. 42; Jones *et al.* 2000, pp. 82–84; Angermeier *et al.* 2004, pp. 19–24; Wheeler *et al.* 2005, pp. 145, 148–149).

Construction and maintenance of roads and highways near riparian areas can be a source of sediment and pollutants (Waters 1995, p. 42; Wheeler *et al.* 2005, pp. 145, 148–149). Sediment can adversely affect fish populations by interfering with respiration; reducing the effectiveness of fish's visually-based hunting behaviors; and filling in interstitial spaces of the substrate, which reduces reproduction and foraging success of fish (Wheeler *et al.* 2005, p. 145). Excessive sediment also fills in intermittent pools that roundtail chub utilize as habitat. Fine sediment pollution in streams impacted by highway construction without the use of sediment control structures was 5 to 12 times greater than control streams (Wheeler et al. 2005, p. 144). Excessive sediment can also affect the ability of roundtail chubs to forage. Sedimentation can alter the aquatic macroinvertebrate community, thereby reducing the food base for roundtail chubs. Increased turbidity may impede the ability of roundtail chubs to forage by reducing underwater visibility (Barrett *et al.* 1992, p. 437; Waters 1995, pp. 173–175).

Contaminants (hydrocarbons such as petroleum based products, and metals, including iron, zinc, lead, cadmium, nickel, copper, and chromium) are associated with highway construction and use (Foreman and Alexander 1998, p. 220; Wheeler *et al.* 2005, pp. 146– 149). Many of these contaminants are suspected toxicants to aquatic organisms. Few studies have addressed the toxicity of highway runoff, but some comparisons of macroinvertebrate communities above and below highway crossings indicate that there are reductions in diversity and pollution-sensitive species below highway crossings, especially where small streams receive runoff from large highway sections (Wheeler *et al.* 2005, p. 148). In areas with cold winter weather conditions, deicing is common to clear snow and ice from roadways. Deicing can contribute sodium chloride and other chemical contaminants to water ways, reducing water quality, which can cause fish stress or mortality (Wheeler *et al.* 2005, p. 147). Roads also inevitably contribute to contaminant spills from vehicle accidents. Most hazardous chemicals are transported by trucks, and such spills are common, and can contaminate water bodies and cause fish kills (Wheeler *et al.* 2005, pp. 147– 148).

Road construction can also impact roundtail chub through physical changes to the stream channel. Channelization, often a necessary component of urban road construction, can have numerous effects on the natural structure and ecosystem function of stream systems (Poff *et al.* 1997, p. 773; Poole 2002, p. 641). As discussed in the ‘‘Logging, Fuel Wood Cutting, Mining, and Channelization’’ section, channelization can affect roundtail chub habitat by reducing its complexity, eliminating cover, reducing nutrient input, improving habitat for nonnative species, changing sediment transport, altering substrate size, and reducing the length of the stream and therefore the amount of aquatic habitat available (Gorman and Karr 1978, p. 507; Simpson *et al.* 1982, pp. 122–132; Propst 1999, p. 25; Schmetterling *et al.* 2001, p. 6).

Roads can restrict the movement of stream fishes, resulting in populations becoming more isolated and fragmented. Culverts, a common feature of road stream crossings, are a well-known barrier to fish movement. Culverts themselves provide poor fish habitat due to low-bottom complexity and uniformly high-flow velocities (Slawski and Ehlinger 1998, p. 676). Fish movement is inhibited or prevented by high current velocities and shallow depths inside culverts, along with vertical drops commonly associated with the culvert outflow (U.S. Department of Transportation 2007, pp. 3–9). Warren and Pardew (1998, p. 637) found that overall fish movement was an order of magnitude lower through culverts than through other crossing types or natural channels in small streams. Such barriers can isolate fish populations, resulting in reduced genetic diversity and increased probability of extinction due to demographic instability and impeded recolonization. Fragmentation of roundtail chub habitat increases the probability of local extirpation (Fagan et al. 2002, p. 3250).

By definition, roads create access to otherwise inaccessible areas or increase access to previously remote areas. This increased access results in increased human visitation, thereby increasing the frequency and significance of anthropogenic threats to aquatic ecosystems and further fragmenting the landscape. Further, increased access often leads to increased urban and agricultural development. Urbanization is the most significant of these development activities; it alters a watershed, such as through building construction, which changes rural areas from such uses as farming and grazing to residential and industrial areas. Wheeler *et al.* (2005; pp. 149–150) concluded that ‘‘new highways clearly and purposely provide impetus for urban development’’ although they noted that few studies, if any, have specifically documented this. Roads nonetheless do clearly have a relationship to urban and rural development, which can alter physical and chemical characteristics of streams due to increases in contaminants and changes to the watershed that alter stream flow, as discussed in the ‘‘Urban and Rural Development’’ section above.

Recreation

As discussed above, population growth trends are expected to continue into the future throughout the range of the roundtail chub in the lower Colorado River basin, dramatically increasing human populations. Expanding population growth leads to higher demand for recreational opportunities and recreational use. In the arid Southwest, the human desire to recreate in or near water, and the relative scarcity of such recreational opportunities, tends to focus impacts on riparian areas. Recreation-related impacts to aquatic ecosystems are particularly evident along stream reaches of the Salt and Verde River watersheds near the Phoenix metropolitan area, which are visibly degraded by ongoing use. Impacts of recreation are highly dependent on the type of activity, with activities such as hiking having little impact and activities such as off-highway vehicle (OHV) use potentially having severe impacts on aquatic habitats.

An example of a recreation use impacted area within the existing distribution of the roundtail chub is the Verde Valley. The reach of the Verde River that winds through the Verde Valley receives a high amount of recreational use from people living in central Arizona (Paradzick *et al.* 2006, pp. 107–108). Increased human use results in trampling of nearshore vegetation and reduced water quality. Recreational impacts in Fossil Creek illustrate that such damage can be quite severe. Fossil Creek is a tributary of the Verde River and an extant locality of roundtail chub. A number of environmental groups recently sent a letter to the Coconino National Forest requesting emergency action to address the effects of ongoing recreational use in Fossil Creek. The authors cited excessive and damaging impacts of recreational uses on the creek and riparian habitat, including vehicles crushing vegetation, proliferation of social trails, kayak impacts, severe sanitation deficiencies, and an exceptional amount of trash (American Rivers *et al.* 2007, pp. 1–4). The effects to roundtail chub from these actions are unknown, but potentially adverse.

OHV use has grown considerably in Arizona, and is a recreational use that can have severe adverse impacts to natural areas. As of 2007, 385,000 OHVs were registered in Arizona (a 350 percent increase since 1998) and 1.7 million people (29 percent of the Arizona's public) engaged in off-road activities from 2005–2007. Over half of OHV users reported that driving off-road was their primary activity, versus using the OHV for the purpose of access or transportation to hunting, fishing, or hiking. Ouren *et al.* (2007, pp. 16–22) provide additional data on the effects of OHV use on wildlife. OHV trails often travel through undeveloped habitat and cross directly through water bodies. OHV use may also reduce vegetation cover and plant species diversity, reducing infiltration rates, increasing erosion, and reducing habitat connectivity (Ouren *et al.* 2007, pp. 6– 7, 11, 16). As discussed above, reducing vegetative cover and increasing sedimentation is a result of other land uses as well, such as livestock grazing and urbanization, and can have numerous adverse effects to roundtail chub. Voeltz (2002) noted specific OHV use-related problems with recreation in two streams with known populations of roundtail chub, the upper Gila River and Oak Creek. Recreation occurs in every stream occupied by roundtail chub in the lower Colorado River basin (Cantrell 2009, p. 15).

Logging, Fuel Wood Cutting, Mining, and Channelization

Logging and mining were more widespread historically and likely were responsible for alteration of much of the roundtail chub's historical habitat. Chamberlain in 1904 listed mining as one of three primary causes of ''extinction'' of fishes in the lower Colorado River basin (along with vegetation removal from grazing, logging and other activities, and water use) (Minckley 1999, p. 215). The current mining of sand, gravel, iron, gold, copper, or other materials remains a potential threat to the habitat of roundtail chub for many of these same reasons. Drilling for fuels such as oil and natural gas has very similar effects (Hartman 2007, p. 1) and is occurring within the range of the roundtail chub in Arizona (Cantrell 2009, p. 12). The effects of mining activities on populations include adverse effects to water quality and lowered flow rates due to dewatering of nearby streams needed for mining operations (Arizona Department of Environmental Quality 1993, pp. 61–63). Sand and gravel mining removes riparian vegetation and destabilizes streambanks, resulting in habitat loss for the roundtail chub (Brown *et al.* 1998, p. 979). Voeltz (2002, pp. 34–35, 42) identified mining as a significant threat in Boulder, Burro, and Eagle creeks due to the release of toxic effluents into aquatic systems from mining operations, and water depletion for use in mining operations, and noted that contaminants in the form of acidified flows originating from mining operations in Cananea, Mexico, have been documented in the past in the San Pedro River, a stream in which the roundtail chub no longer occurs. Girmendonk and Young (1997, p. 35) noted that sand and gravel mining on West Clear Creek may have limited the suitability of that stream to support roundtail chub near the mouth of the Verde River. Mining is a land use in the basins of 24 out of 31 currently extant roundtail chub populations (Voeltz 2002; Cantrell 2009, p. 6).

Logging and fuel wood cutting is largely a threat of the past (resulting from previous management practices no longer in place), although these activities resulted in profound changes in many streams of the Southwest including those in which the roundtail chub occurs (Minckley and Rinne 1985, pp. 150–151; Minckley 1999, p. 216). The alteration of watersheds resulting from logging is deleterious to fish and other aquatic life forms (e.g., Burns 1972, p. 1; Eaglin and Hubert 1993, p. 844), largely due to increases in surface runoff, sedimentation, and mudslides, and the destruction of riparian vegetation (Lewis 1998, p. 55; Jones *et al.* 2000, p. 81). All of these effects negatively impact fish (Burns 1972, p. 15; Eaglin and Hubert 1993, p. 844; Barrett *et al.* 1992, p. 437; Warren and Pardew 1998, p. 637) by lowering water quality and reducing the quality and quantity of pools, either by filling them with sediment, reducing the quantity of large woody debris necessary to form pools, or imposing barriers to movement. Logging is a land use in the watersheds of 17 of the remaining 31 streams known to contain roundtail chub populations (Voeltz 2002).

Channelization of streams is also a major factor in loss of habitat for roundtail chub. The U.S. Environmental Protection Agency defines channelization as: ‘‘any activity that moves, straightens, shortens, cuts off, diverts, or fills a stream channel, whether natural or previously altered. Such activities include the widening, narrowing, straightening, or lining of a stream channel that alters the amount and speed of the water flowing through the channel. Examples of channelization are: lining channels with concrete; pushing gravel from the stream bed and placing it along the banks; and placing streams into culverts’’ (U.S. Environmental Protection Agency 2005, p. 1). Channelization has occurred or is occurring in roundtail chub habitats to drain marshes and reclaim bottomlands for agriculture or roads (Hendrickson and Minckley 1984, p. 131; Propst 1999, p. 25); to create irrigation diversions; to control mosquitoes; to reduce evapotranspiration and speed water delivery to downstream metropolitan and agricultural areas (U.S. Soil Conservation Service 1949, p. 3; Burkham 1970, p. B1); and as flood control to protect fields, buildings, or structures such as bridges (Pearthree and Baker 1987, p. 49). Channelization can affect roundtail chub habitat by reducing its complexity, eliminating cover, reducing nutrient input, improving habitat for nonnative species, changing sediment transport, altering substrate size (usually from coarse sediments like gravel and sand to a finer silt substrate), and reducing the length of the stream and therefore the amount of aquatic habitat available (Gorman and Karr 1978, p. 513; Simpson *et al.* 1982, pp. 122–132; Propst 1999, p. 25; Schmetterling *et al.* 2001, p. 6; U.S. Environmental Protection Agency 2005, pp. 1–4). Moyle (1976, p. 179) compared channelized and unchannelized sections of a California stream and found a two-thirds reduction in the biomass of fish and invertebrates in channelized locations compared to unchannelized reaches, as well as differences in fish and macroinvertebrate (animals lacking a vertebral column, such as aquatic insects) species composition. Channelization may reduce the recruitment of fishes by eliminating nursery habitat through the removal of gradually sloping streambanks, reducing the extent of nearshore habitats with low water velocity (Scheidegger and Bain 1995, p. 125; Me´rigoux and Ponton 1999, p. 177; Meng and Matern 2001, p. 750).

High-Intensity Wildfires

Low-intensity fire has been a natural disturbance factor in forested landscapes for centuries, and lowintensity fires were common in southwestern forests and grasslands prior to European settlement (Rinne and Neary 1996, pp. 135–136). Rinne and Neary (1996, p. 143) discuss the current effects of fire management policies on aquatic communities in Madrean Oak Woodland biotic communities, a community type that comprises large portions of some watersheds occupied by roundtail chub. They concluded that existing wildfire suppression policies intended to protect the expanding number of human structures on forested public lands have altered the fuel loads in these ecosystems and increased the probability of devastating wildfires. Other researchers have also found that fire suppression policies in combination with other land uses have increased the probability of high-intensity fire due to past land use, fire suppression, and unnaturally high fuel loadings (Cooper 1960, pp. 161–162; Covington and Moore 1994, pp. 45–46; Swetnam and Baison 1994, pp. 12–13; Touchan *et al.* 1995, pp. 268–272; White 1985, p. 589). Not surprisingly, the intensity (size and severity) of forest fires has increased in recent times (Covington and Moore 1994, p. 40; Westerling *et al*. 2006, p. 940).

The effects of these catastrophic wildfires include the removal of vegetation, the degradation of watershed condition, altered stream behavior, and increased sediment and ash flows into streams. These effects can harm fish communities, as observed in the 1990 Dude Fire, when corresponding ash flows drastically reduced some fish populations in Dude Creek and the East Verde River (Voeltz 2002, p. 77). Fire has become an increasingly significant threat in lower-elevation communities as well. Esque and Schwalbe (2002, pp. 180–190) discuss the effect of wildfires in the upper and lower subdivisions of Sonoran desertscrub. The widespread invasion of nonnative annual grasses, such as brome (*Bromus sp*.) and Mediterranean grasses (*Schismus sp.*), appear to be largely responsible for altered fire regimes that have been observed in these communities, which are not adapted to fire (Esque and Schwalbe 2002, p. 165). African buffelgrass (*Pennisetum ciliare*) is recognized as another invading nonnative plant species throughout the lower elevations of northern Mexico and Arizona. Nijhuis (2007, pp. 1–7) discusses the spread of nonnative buffelgrass within the Sonoran Desert of Arizona and adjoining Mexico, citing its ability to out-compete native vegetation and present significant risks of fire in an ecosystem that is not adapted to fire. In areas comprised entirely of native plant species, ground vegetation density is mediated by barren spaces that do not allow fire to carry itself across the landscape. However, in areas where nonnative grasses have become established, the fine fuel load is continuous, and fire is capable of spreading quickly and efficiently (Esque and Schwalbe 2002, p. 175). These nonnative grasses thus increase the potential for catastrophic wildfire.

After disturbances such as fire, nonnative grasses may exhibit dramatic population explosions, which hasten their effect on native vegetative communities. Additionally, with increased fire frequency, these population explosions ultimately lead to a type-conversion of the vegetative community from desertscrub to grassland (Esque and Schwalbe 2002, pp. 175–176). Fires carried by the fine fuel loads created by nonnative grasses often burn at unnaturally high temperatures, which may result in soils becoming hydrophobic (water repelling), exacerbate sheet erosion, and contribute large amounts of sediment to receiving water bodies, thereby affecting the health of the riparian community (Esque and Schwalbe 2002, pp. 177– 178). The siltation of isolated, remnant pools in intermittent streams significantly affects lower-elevation species by increasing the water temperature, reducing dissolved oxygen, and reducing or eliminating the permanency of pools, as observed in pools occupied by lowland leopard frogs (*Rana yavapaiensis*) and native fish (Esque and Schwalbe 2002, p. 190).

Fires in the Southwest frequently occur during the summer monsoon season. As a result, fires are often followed by rain that washes ash-laden debris into streams. Rinne (2004, p. 151) found significant reductions in fish abundance as a result of these ash flows, ranging from 70 to 100 percent. Extreme summer fires, such as the 1990 Dude Fire, and corresponding ash flows, have drastically reduced some fish populations. Some recent examples of extreme summer fires that have reduced native fish populations include the 2002 Rodeo-Chedeski Fire, the 2003 Aspen Fire, and the 2004 Willow Fire, all of which burned parts of watersheds occupied by roundtail chub. Carter and Rinne (unpubl. data) found that the Picture Fire both benefited and eliminated headwater chub, a closely related species that occurs in similar habitat, from portions of Spring Creek. The fire eliminated chubs from Turkey Creek, a tributary to Spring Creek. In other parts of Spring Creek, however, chubs initially declined but later thrived after the fire, presumably because most of the nonnative fishes were eliminated.

Dunham *et al.* (2003, pp. 189–190) examined how fire affects nonnative species invasions; although habitat alteration over time can facilitate nonnative species with wider habitat tolerances, native species may be better able to withstand ash flows and flooding. Thus immediately post-fire, nonnatives may be completely eliminated and the few natives present can take advantage of the reduction in predators. But such events, at a minimum, represent a genetic bottleneck (drastic reduction in population size) for the species that could adversely impact populations via genetic threats, such as inbreeding depression (reduced health due to elevated levels of inbreeding) and genetic drift (a reduction in gene flow within the species that can increase the probability of unhealthy traits) (Meffe and Carrol 1994, pp. 156–167). Many roundtail chub populations are fragmented and isolated. Fagan *et al* (2002, p. 3254) found that, as a result of this fragmentation and isolation, roundtail chub has moderately high risk of local extirpation. Dunham *et al.* (2003, pp. 188–189) found that the threat of fire to fish populations is much greater for highly fragmented and isolated populations of fishes.

Undocumented Immigration and International Border Enforcement and Management

Cantrell (2009, p. 12) indicated that undocumented immigration and international border enforcement and management could be a threat in nine areas occupied by roundtail chub. Because the roundtail chub is extirpated from most of the southern portions of its range, such as the San Pedro River, this threat is more likely to affect potential recovery areas than currently occupied habitats, but is a possible threat in some occupied streams. Undocumented immigrants and smugglers attempt to cross the international border from Mexico into the United States in areas historically and currently occupied by the roundtail chub. These illegal border crossings and the corresponding efforts to enforce U.S. border laws and policies have been occurring for many decades with increasing intensity and have resulted in unintended adverse effects to biotic communities in the border region. During the warmest months of the year, many attempted border crossings occur in riparian areas that serve to provide shade, water, and cover. Increased U.S. border enforcement efforts that began in the early 1990s in California and Texas have resulted in a shift in crossing patterns and increasingly concentrated levels of attempted illegal border crossings into Arizona (Segee and Neeley 2006, p. 6).

Traffic on new roads and trails from illegal border crossing and enforcement activities, as well as the construction, use, and maintenance of enforcement infrastructure (e.g., fences, walls, and lighting systems), leads to compaction of streamside soils, and the destruction and removal of riparian vegetation. Current border infrastructure projects, including vehicle barriers and pedestrian fences, are located specifically in valley bottoms and have resulted in direct impacts to water courses and altered drainage patterns (Service 2008, p. 4). These activities also produce sediment in streams, which affects their suitability as habitat for roundtail chub by reducing their permanency and altering their physical and chemical parameters. Riparian areas along the upper San Pedro River have been impacted by abandoned fires that undocumented immigrants started to keep warm or prepare food (Segee and Neeley 2006, p. 23).

Undocumented immigrants use wetlands for bathing, drinking, and other uses (Segee and Neeley 2006, pp. 21–22). These activities can contaminate the water quality of the wetlands and lead to reductions in habitat quality for roundtail chub (Rosen and Schwalbe 1988, p. 43; Segee and Neeley 2006, pp. 21–22). In addition, numerous observations of littering and destruction of vegetation and wildlife occur annually throughout the border region, which can adversely affect the quality of habitat for the roundtail chub (Service 2006, p. 95).

Conservation Actions Relevant to Factor A

There are several existing conservation agreements for native fish species that include roundtail chub (discussed in detail in Factor E below): the Utah Department of Natural Resources' ''Range-wide conservation agreement and strategy for roundtail chub (*Gila robusta*), bluehead sucker (*Catostomus discobolus*), and flannelmouth sucker (*Catostomus latipinnis*)'' (Range-wide Agreement; Utah Department of Natural Resources 2002); the New Mexico Department of Game and Fish's (NMDGF) ''Colorado River Basin Chubs Recovery Plan'' (New Mexico Plan; Carman 2006), which includes the headwater and Gila chubs; and the AGFD's ''Arizona Statewide Conservation Agreement for Roundtail Chub (*Gila robusta*), Headwater Chub (*Gila nigra*), Flannelmouth Sucker (*Catostomus latipinnis*), Little Colorado River Sucker (*Catostomus* spp.), Bluehead Sucker (*Catostomus discobolus*), and Zuni Bluehead Sucker (*Catostomus discobolus yarrowi*)'' (Arizona Agreement; AGFD 2006).

The Range-wide Agreement, Arizona Agreement, and New Mexico Plan all include actions intended to reduce the threat of habitat loss. The Range-wide Agreement recommends enhancing and maintaining habitat for roundtail chub, including: Enhance and/or restore connectedness and opportunities for migration of the subject species to disjunct populations where possible; restore altered channel and habitat features to suitable conditions; provide flows needed for all life stages; maintain and evaluate fish habitat improvements; and install regulatory mechanisms for the long-term protection of habitat (e.g., conservation easements, water rights). The Arizona Agreement identifies the need to secure, enhance, and create habitat as one of its conservation strategy tasks and includes these subtasks:

(1) Maintain instream flow;
(2) Manage detrimental nonnative fish and other aquatic species;
(3) Evaluate effectiveness of nonnative management efforts;
(4) Restore natural fire regimes;
(5) Manage the spread of infectious diseases and parasites to habitats of the subject species;
(6) Enhance and/or restore connectedness;
(7) Develop appropriate flow recommendations for areas where existing flow regimes are

inadequate;
(8) Implement flow recommendations;
(9) Restore altered channel and habitat features;
(10) Create, maintain, and evaluate fish refugia throughout historic range;
And
(11) Maintain habitat quality.

The New Mexico Plan identifies the need to address habitat loss, including:
(1) Identify and determine habitat requirements for all life history stages of roundtail chub in the San Juan and Gila River basins;
(2) Support efforts within existing programs to enable habitat restoration and protection for recovery;
(3) Identify and secure resources to promote habitat restoration and protection;
(4) Rehabilitate, restore, and secure historical habitats where chub restoration is possible;
(5) Inform private and public landowners about practices that promote diverse, functional aquatic and riparian habitats;
(6) Inform private and public landowners about how to protect chub habitat;
(7) Identify and secure funding to promote habitat restoration and protection; and
(8) Establish formal agreements with willing participants to enhance habitat and/or populations for recovery of roundtail chub.

Several actions are planned or have been implemented as a result of the conservation agreements that address the threat of habitat loss. They are discussed below.

The Nature Conservancy (Conservancy) is a signatory to the Arizona Agreement. In Arizona, the Conservancy has launched its Nature Matters fundraising campaign. This program raises private donations to support cooperative land and water protection projects. The Conservancy contacts landowners to explore their interest in placing their property in a permanently protected status, then works cooperatively with its agency partners to negotiate purchase and sale agreements and to develop fundraising proposals and project financing. Properties are identified and prioritized based on the quality of their riparian and aquatic habitat as well as opportunities to secure surface water rights or to file for new water rights to maintain instream flow.

In 2007, the Conservancy purchased the Upper Verde River Wildlife Area, a 313-acre (ac) (127-hectare (ha)) parcel downstream from the Verde River confluence with Granite Creek near Paulden, Arizona. The Conservancy later received the donation of an additional 160 ac (65 ha). In total, the acquisition secured the largest remaining portion of the Verde River headwaters still in private ownership and protects roughly 1 mi (1.6 km) of high quality riparian and aquatic habitat from development and improper livestock grazing. In 2008, the Conservancy conveyed 293 ac (119 ha) of this property to the AGFD to be added to the Upper Verde River Wildlife Area. In July of 2008, the Conservancy and AGFD each filed for instream flow water rights with the Arizona Department of Water Resources for the properties.

In 2008, the Conservancy completed two land acquisitions on the middle Verde River within the 33-mi (53-km) stretch that Arizona State Parks has designated for acquisition as the Verde River Greenway: a 20-ac (8-ha) parcel upstream of Camp Verde that is adjacent to U.S. Forest Service frontage on the river; and the 209-ac (85-ha) Rockin' River Ranch property purchased with Arizona State Parks. The Rockin' River property, located at the confluence of the Verde River and West Clear Creek, includes 55 ac (22 ha) under irrigation with surface water rights dating back to 1889. Protection of the property provides an opportunity to retire and dedicate water rights to instream flow for the benefit of wildlife including roundtail chub. The Conservancy continues to meet with landowners on a willing-seller basis to explore opportunities to protect additional lands along the river and in the Big Chino Valley, which overlays the aquifer that is the primary groundwater source for the upper Verde River, and to pursue private and public funding to support land and water protection in the Verde watershed. These actions could help secure instream flow and protect riparian areas from harmful land uses, benefitting roundtail chub.

In 2006, the Conservancy received as a donation the Cobra Ranch property at the headwaters of Aravaipa Creek near Klondyke, Arizona. The addition of this property to the Conservancy's Aravaipa Canyon Preserve protects over 1 mi (1.6 km) of stream channel and presents significant habitat restoration opportunities. The Conservancy plans to restore native vegetation on 100 ac (40 ha) of farm ground, and retire irrigation, which will reduce draw-down of the aquifer and create improved infiltration patterns on the farm. They will also strategically plant native vegetation along the active channel to restore the natural river channel. Fencing is being installed to remove grazing from riparian areas, and planning is ongoing to restore a natural fire regime. These actions will serve to restore a historical cienega that once existed in the headwaters of Aravaipa Creek, and will reduce overgrazing, dewatering, and sedimentation effects to the roundtail chub in Aravaipa Creek.

The U.S. Forest Service is also a signatory to the Arizona Agreement. The Tonto National Forest is working to establish an instream flow water right on approximately 36 mi (58 km) of U.S. Forest Service lands along Cherry Creek from its headwaters to the confluence with the Salt River. Once in place, the water right should protect enough flow to provide for roundtail chub habitat in perpetuity. Similarly, through the Horseshoe and Bartlett Habitat Conservation Plan, Salt River Project (SRP), a large water and electricity provider for portions of Arizona, is implementing watershed management efforts to maintain or improve stream flows in the Verde River, including funding of stream gages and scientific studies, in-kind support for watershed improvements, and administrative and legal efforts to curtail stream flow reductions from illegal surface water diversions and groundwater pumping.

The Arizona Agreement also includes provisions for addressing the threat of catastrophic wildfire. A conservation strategy task is to restore natural fire regimes in the watersheds of extant populations of roundtail chub, including securing habitat through the use of prescribed fire and noncommercial understory thinning to restore natural fire regimes. Controlled prescribed fires reduce the risk of catastrophic wild fires by reducing fuel loads. The New Mexico Plan also identifies the need to support research to determine the tolerance of roundtail chub to water quality parameters, particularly those that may be altered during and after forest fires.

Summary of Factor A

Rivers, streams, and riparian habitats that are essential for the survival of the roundtail chub are being adversely affected and eliminated throughout the range of the species. Threats, including water diversions, groundwater pumping, dams, channelization, and erosion-related effects, are occurring that impact both the amount of water available for habitat, as well as the water's suitability for roundtail chub. Threats from flood control, development, roads, water withdrawal, improper livestock grazing, recreation, and high-intensity wildfire dry up, silt in, physically alter, and chemically pollute habitats of the roundtail chub such that habitats become permanently unsuitable. These threats have been documented historically and are either occurring or likely to occur throughout the range of the roundtail chub. These threats reduce the habitat's suitability as cover for protection from predators, as a foraging area, and as spawning and nursery areas. Despite the conservation actions discussed above, the dewatering of aquatic habitats in the arid lower Colorado River basin poses a significant threat to all native fish of the region, including roundtail chub. All of these threats are anthropogenic and can be expected to continue, if not increase, given the predictions for increases in human population expansion in the region. Efforts to ameliorate these threats through established conservation agreements have met with some success, but are in the early stages of implementation.

B. Overutilization for commercial, recreational, scientific, or educational purposes.

Overutilization of roundtail chub for commercial, recreational, scientific, or educational purposes is not considered a significant threat to the roundtail chub in the lower Colorado River basin. Roundtail chub is a permitted sport fish in Arizona (AGFD 2008). One roundtail chub greater than 13 in. (33 cm) is allowed via angling per day. The AGFD has also established a catch-and-release only, artificial fly and lure only, single barbless hook, 7-month fishing season for roundtail chub in Fossil Creek. A 4.5-mi (7.2-km) middle reach segment of Fossil Creek will be open to catch-and-release fishing for roundtail chub from Oct 3, 2009, through April 30, 2010. The remainder of the year, the area is closed to all fishing. But angler use of roundtail chub is light (C. Cantrell, AGFD, pers. comm. 2009), and we do not believe that overutilization from current levels of angling is a threat to the species in Arizona. In the upper Gila River in New Mexico, where the species is not a legal sport fish (NMDGF 2008), there are reports of anglers purposefully discarding chub species, which may be having a negative effect on populations of roundtail chub locally (Voeltz 2002). New Mexico is working to include specific information about by-catch, take, and release of non-sportfish species in their fishing proclamation and this may be accomplished in the next year (S. Carman 2010, pers. comm.).

Several studies of fish species closely related to roundtail chub indicate that handling for scientific purposes (research and monitoring) may have some adverse effects on individual fish. Ruppert and Muth (1997, p. 314) found that electrofishing caused spinal hemorrhages in some juvenile humpback chub (*G. cypha*), a closely related species to roundtail chub, but did not affect short-term growth or survival. Paukert *et al.* (2005, p. 649) found that use of hoop nets affected fish growth and condition of bonytail; fish captured multiple times grew less in length and weight than fish not recaptured. Fish recaptured up to five times grew only 12.8 percent of their initial weight compared to fish not recaptured, which grew 29.7 percent of their initial weight. Ward *et al.* (*in press*) also found some mortality from use of passive integrated transponder tags in related Gila chub (*G. intermedia*) and bonytail, although mortality rate was low. We believe the level of handling of roundtail chubs for scientific purposes is low, and the results of these studies suggest that handling roundtail chubs for scientific purposes is not a significant threat to the species.

Conservation Actions Relevant to Factor B

Overutilization of roundtail chub is not believed to be a threat to the species and is therefore not addressed in conservation planning efforts. All three conservation agreements include action items to identify threats; thus, if there is some unidentified threat from overutilization or the degree of the threat has been underestimated, the conservation agreements should serve to help identify this in the future.

Summary of Factor B

Although roundtail chub is a legal sport fish in Arizona, available information indicates that the species is not threatened by overutilization as a game species from current levels of angling. There is some information that collection for scientific purposes has some adverse effects on individual fish; however, we do not believe that handling roundtail chubs for scientific purposes is a significant threat to the species.

C. Disease or predation.

Nonnative Species

Nonnative species that compete with or prey on roundtail chub are a serious and persistent threat to the continued existence of the roundtail chub. Nonnative aquatic species include fishes, aquatic and semi-aquatic mammals, reptiles, amphibians, crustaceans, mollusks (snails and clams), insects, zooplankton, phytoplankton, parasites, disease organisms, algae, and aquatic and riparian vascular plants. The introduction and spread of nonnative species has long been identified as one of the major factors in the continuing decline of native fishes throughout North America and particularly in the Southwest (Miller 1961, p. 365; Lachner *et al.* 1970, pp. 1–4; Ono *et al.* 1983, p. 90; Minckley and Deacon 1991; Carlson and Muth 1989, p. 220; Cohen and Carlton 1995, p.1; Fuller *et al.* 1999, pp. 1–3; Clarkson *et al.* 2005, p. 20; Mueller 2005, pp. 10–12; Olden and Poff 2005, p. 75). Nonnative species may affect native fish and other aquatic fauna through numerous means, including (all of which may be applicable to the roundtail chub): Predation (Meffe *et al.* 1983, p. 316; Meffe 1985, p. 173; Marsh and Brooks 1989, p. 188; Propst *et al.* 1992, p. 177; Blinn *et al.* 1993, p. 139; Rosen *et al.* 1995, p. 251), competition (Lydeard and Belk 1993, p. 370; Baltz and Moyle 1993, p. 246; Scoppotone 1993, p. 139; Douglas *et al.* 1994, pp. 15–17), aggression (Meffe 1984, p. 1525; Karp and Tyus 1990, p. 25), habitat disruption (Hurlbert *et al.* 1972, p. 639; Fernandez and Rosen 1996, p. 3), introduction of diseases and parasites (Clarkson *et al.* 1997, p. 66; Robinson *et al.* 1998, p. 599), and hybridization (Dowling and Childs 1992, p. 355; Echelle and Echelle 1997, p. 153). Because the impacts of competition with and predation by nonnative species are often interrelated and difficult to discuss separately, we will discuss all impacts of nonnative species in this section.

In an evolutionary context, the native fish community of the lower Colorado River basin, including roundtail chub, evolved with low species diversity and with few predators and competitors and thus co-evolved with few predatory fish species. In contrast, many of the nonnative species co-evolved with high species diversity and many predatory species (Clarkson *et al.* 2005, p. 21). A contributing factor to the decline of native fish species cited by Clarkson *et al.* (2005, p. 21) is that most of the nonnative species evolved behaviors, such as nest guarding, to protect their offspring from these many predators, while native species are generally broadcast spawners that provide no parental care. In the presence of nonnative species, the reproductive behaviors of native fish fail to allow them to compete effectively with the nonnative species, and, as a result, the viability of native fish populations is reduced.

In the Southwest, Miller *et al.* (1989, p. 22) concluded that introduced nonnatives were a causal factor in 68 percent of the fish extinctions in North America in the last 100 years. For 70 percent of those fish still extant, but considered to be endangered or threatened, introduced nonnative species are a primary cause of the decline (Aquatic Nuisance Species Task Force 1994; Lassuy 1995, p. 391). The widespread decline of native fish species from the arid southwestern United States and Mexico from interactions with nonnative species has been manifested in the listing rules of nine native species listed under the Act whose historical ranges overlap with the historical and current distribution of the roundtail chub: Bonytail (*G. elegans*) (45 FR 27710; April 23, 1980), humpback chub (*G. cypha*) (32 FR 4001; March 11, 1967), Gila chub (*G intermedia*) (70 FR 66663; November 2, 2005), Colorado pikeminnow (*Ptychocheilus lucius*) (32 FR 4001; March 11, 1967), spikedace (Meda fulgida) (51 FR 23769; July 1, 1986), loach minnow (*Tiaroga cobitis*) (51 FR 39468; October 28, 1986), razorback sucker (*Xyrauchen texanus*) (56 FR 54957; October 23, 1991), desert pupfish (*Cyprinodon macularius*) (51 FR 10842; March 31, 1986), and Gila topminnow (*Poeciliopsis occidentalis*) (32 FR 4001; March 11, 1967). In total within Arizona, 19 of 31 (61 percent) native fish species are listed under the Act. Arizona ranks the highest of all 50 states in the percentage of native fish species with declining trends (85.7 percent, Stein 2002, p. 21; Warren and Burr 1994, pp. 6–18). I n the Gila River basin, introduction of nonnatives is considered a major factor in the decline of all native fish species (Miller 1961, pp. 377–379; Williams *et al.* 1985, p. 1; Minckley and Deacon 1991). In Arizona, release or dispersal of new nonnative aquatic organisms is a continuing phenomenon (Rosen *et al.* 1995, p. 259; Service 2008, p. 264).

Aquatic nonnative species are introduced and spread into new areas through a variety of mechanisms, both intentional and accidental, and authorized and unauthorized. Mechanisms for nonnative dispersal in the southwestern United States include inter-basin water transfer (Service 2008, p. 1), sport fish stocking (Clarkson *et al.* 2005, p. 20), aquaculture and aquarium releases (Courtenay 1993, pp. 35–62; Crossman 1991, p. 46; Crossman and Cudmore 2000, pp. 129–134; Mackie 2000, pp. 135–150), bait-bucket release (release of fish used as bait by anglers) (Crossman 1991, p. 50; Litvak and Mandrak 1993, p. 6), and to control other species (such as the introduction of herbivorous fish to control aquatic plants) (Bailey 1978, p. 181; Courtney 1993, p. 37).

In the Verde River system alone, Rinne *et al.* (1998, p. 3) estimated that over 5,300 independent stocking actions occurred that involved 12 different species of nonnative fish species since the 1930s and 1940s. If we extrapolate that effort over the same timeframe for other historically occupied, larger-order systems known as recreational fisheries (such as the Salt, upper Gila, Bill Williams, and San Pedro rivers, and Oak Creek and other tributaries with significant flow throughout central and southern Arizona), in addition to the other private stockings of stock tanks and other isolated habitat, the magnitude of the nonnative species invasion over this timeframe becomes clear. Subsequent to these efforts, but to a lesser extent, the spread of bullfrogs and crayfish, both purposefully and incidentally, commenced during the 1970s and 1980s (Tellman 2002, p. 43). We estimate that nearly 100 percent of the habitat that historically supported roundtail chub has been invaded over time, either purposefully or indirectly through dispersal, by nonnative fishes and other aquatic species.

Nonnative fishes known from within the historical range of roundtail chub in the lower Colorado River basin include channel catfish (*Ictalurus punctatus*), flathead catfish (*Pylodictis olivaris*), red shiner (*Cyprinella lutrensis*), fathead minnow (*Pimephales promelas*), green sunfish (*Lepomis cyanellus*), warmouth (*L. gulosus*), bluegill (*L. macrochiris*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieui*), rainbow trout (*Oncorynchus mykiss*), western mosquitofish (*Gambusia affinis*), carp (*Cyprinus carpo*), yellow bullhead (*Ameiurus natalis*), black bullhead (*A. melas*), and goldfish (*Carassius auratus*) (Bestgen and Propst 1989, pp. 409–410; Marsh and Minckley 1990, p. 265; Sublette *et al.* 1990, pp. 112, 243, 246, 304, 313, 318; Abarca and Weedman 1993, pp. 6– 12; Stefferud and Stefferud 1994, p. 364; Weedman and Young 1997, p. 1, Appendices B, C; Rinne *et al.* 1998, pp. 3–6; Voeltz 2002, p. 88; Bonar *et al.* 2004, pp. 1–108; Fagan *et al.* 2005, pp. 34, 38–39, 41). The fastest expanding nonnative species are red shiner, fathead minnow, green sunfish, largemouth bass, western mosquitofish, and channel catfish. These species are considered to be the most invasive in terms of their negative impacts on native fish communities (Olden and Poff 2005, p. 75).

Smaller size classes (juvenile and subadult fish) are more vulnerable to predation because the size of a fish that a predatory fish can consume is limited by the predator's gape size. Brouder *et al.* (2000, p. 13) found that size class of native fishes consumed (including roundtail chub) by predatory nonnative fishes in the Verde River was 1.3 to 3.5 in (34 to 90 millimeters (mm)). This winnowing effect results in a population of only large adult fish, which eventually crashes. A spectacular example of this is the case of the razorback sucker in Lake Mohave in Arizona and Nevada. For decades, no recruitment was documented within the population, although large adults (razorback sucker is a large species, with adults up to 20 in. (500 mm) or longer in total length) remained common. This situation was possible because razorback sucker are very long-lived, living 40 years or more (McCarthy and Minckley 1987, p. 87). The population eventually crashed in the 1990s because of a total lack of recruitment due to predation by nonnative fish species on smaller, younger fish, although conservation efforts have resulted in maintenance of a much smaller stocked population (Service 2002a, pp. 9, 11; Mueller 2005, p. 11). A similar population crash likely happened to bonytail, a species closely related to roundtail chub, in Lake Mohave, with the crash happening sooner because bonytail likely have a shorter life span (Service 2002b, p. 11, A–6).

The introduction of more aggressive and competitive nonnative fish has likely led to losses of roundtail chub (Voeltz 2002, p. 88). Dudley and Matter (2000, p. 24) found that nonnative green sunfish prey on, compete with, and virtually eliminate recruitment of Gila chub (a closely related species to roundtail chub) in Sabino Creek in Arizona. Similar effects of green sunfish on Gila chub have been documented in Silver Creek in Arizona (Unmack *et al.* 2004, pp. 86–87), with recruitment of Gila chub effectively eliminated by nonnative green sunfish. In the Verde River mainstem, Bonar et al. (2004, p. 57) found that nonnative fishes were approximately 2.6 times more dense per unit volume of river than native fishes, and their populations were approximately 2.8 times that of native fishes per unit volume of river. Bonar *et al.* (2004, pp. 6–7) found that largemouth bass, smallmouth bass, bluegill, green sunfish, channel catfish, flathead catfish, and yellow bullhead all consumed native fish; although roundtail chub was not detected in the diet of any nonnative fishes, this is likely only due to the relative rarity of the species compared with other native fish, as well as the short time necessary for a fish to be digested. Roundtail chubs have been found in stomachs of largemouth bass in the lower Salt River (P. Unmack, Arizona State University, pers. comm. 2008). Bestgen and Propst (1989, p. 406) reported that, of nonnatives present in New Mexico, smallmouth bass, flathead catfish, and channel catfish most impacted roundtail chub via predation. Native fishes, including roundtail chub, have experienced significant declines in the Salt River above Roosevelt Lake, concurrent with a significant increase in flathead and channel catfish numbers (Creef and Clarkson 1992, p. 5; Jahrke and Clark 1999 p. 9). Brouder *et al.* (2000, p. 9), based on population estimates, determined that nonnative species were likely suppressing roundtail chub populations in two areas of the upper Verde River. Yard *et al.* (2008) found that rainbow trout predation on humpback chub in Grand Canyon likely resulted in significant levels of humpback chub mortality (Yard *et al.* 2008, p. 53).

In some areas, the presence of nonnative species appears to be limiting recruitment of roundtail chub, with only large adults encountered during surveys (Cantrell 2009, p. 10). Red shiner is known to compete with native southwestern cyprinids (Minckley and Deacon 1968, pp. 1427–1428; Minckley 1973, p. 138; Douglas *et al.* 1994, p. 9), and prey on larval fishes (Ruppert *et al.* 1993, p. 397). In a study of the roundtail chub population in the lower Salt and Verde Rivers, Bryan and Hyatt (2004, p. 3) estimated adult population size of roundtail chub to be 1,657, and found that this was a 74 percent decrease from just 3 years earlier. Bryan and Hyatt (2004, pp. 12–13) concluded that the roundtail chub population in the lower Salt and Verde rivers was declining rapidly due to low recruitment and high natural mortality, and identified the ‘‘negative impacts of competition and predation [from the] introduction of nonnative fishes into roundtail chub habitat’’ as the likely cause of recruitment failure. They recommended that stocking nonnative sport fish ‘‘be carefully evaluated and probably suspended, especially with regards to predatory species’’ and that stocking rainbow trout ‘‘be thoroughly evaluated to determine its economic impact and the specific impacts to the [roundtail] chub population.’’

Few if any studies of roundtail chub have effectively demonstrated competition with nonnative fishes, although numerous authors have considered it a threat (Bestgen and Propst 1989; Brouder *et al.* 2000; Voeltz 2002; AGFD 2006, p. 5). Bestgen (1985, p. 53) found that diets between rainbow trout and roundtail chub differed to an extent that suggested interactive segregation of habitat and competition for food resources, and although the health of the chub population indicated competition was not severe, in higher densities, trout competition could impact roundtail chub. Dudley and Matter (2000, p. 24) found that green sunfish utilized the same habitats as Gila chub, a closely related species to roundtail chub, and appeared to competitively exclude them from preferred habitats. In the Colorado River in Grand Canyon, Arizona, diet studies of humpback chub and rainbow trout show strong overlap for aquatic invertebrates such as blackfly larvae (*Simuliidae*) and *Gammarus* (Valdez and Ryel 1995; Yard *et al.* 2008), and removal of nonnative trout is one factor suspected to be responsible for a recent increase in humpback chub numbers in Grand Canyon (U.S. Geological Survey 2006, p. 2). But because rainbow and brown trout (*Salmo trutta*) have also been shown to prey on humpback chub in the Grand Canyon (Yard *et al.* 2008), either a reduction in predation of humpback chub, or a reduction in competition with humpback chub, or both, may be responsible. Intuitively, both scenarios seem likely, and this is the conventional wisdom of many researchers studying the effects of nonnative fishes on natives in the southwest United States (Marsh and Douglas 1997; Brouder *et al.* 2000; Voeltz *et al.* 2002; AGFD 2006, p. 5). Interestingly, Bestgen (1985, p. 53) noted that any competition between rainbow trout and roundtail chub would likely be significant only if rainbow trout occurred in high densities, and in Grand Canyon, high densities of rainbow trout appear to be impacting the humpback chub population (Yard et al. 2008; U.S. Geological Survey 2006). Marks *et al.* (*in press*) found that when nonnative fish species were removed, roundtail chub numbers and recruitment increased dramatically. Again, whether this is because nonnative species were preying on or competing with roundtail chub is still a question, but perhaps one that is not necessary to answer, for as Marks *et al.* (2008) illustrate, the remedy for this threat is obvious.

Aquatic habitat alterations due to land use practices such as livestock grazing and dams and dam operation may facilitate the spread and persistence of nonnative fishes. Dams by their very purpose and nature serve to reduce flood flows and increase base flows. Floods have been identified as a potential means to disadvantage nonnative fishes and thereby advantage native fishes (Meffe 1984, p. 1525). Haney *et al.* (2008, p. 61) suggested that diminished river flow due to diversion may be an important factor in loss of native fish from the Verde River. Variation in river flows may provide both advantages and disadvantages to aquatic species. The timing, duration, intensity, and frequency of flood events has been altered to varying degrees by the presence of dams along many stream courses within the range of the roundtail chub, which affects fish communities. Flood pulses may help to reduce populations of nonnative species because, unlike native fish that are adapted to dramatic fluctuations in water conditions and flow regimes (including random high-intensity events, such as flooding, extreme water temperatures, and excessive turbidity), nonnative fishes appear to be less well adapted to such events. Dams, through their amelioration of flood flows and increased base flows, may provide more suitable habitat for nonnative fishes (Meffe 1984, p. 1525; Haney *et al.* 2008, p. 61).

Livestock tanks also may facilitate the persistence and spread of nonnative species of fish, amphibians, and crayfish that are intentionally or unintentionally stocked by anglers and private landowners (Rosen *et al.* 2001, p. 24). The management of stock tanks is an important consideration for native fish restoration. Stock tanks associated with livestock grazing can be intermediary ‘‘stepping stones’’ in the dispersal of nonnative species from larger source populations to new areas, and serve as source populations themselves (Rosen *et al.* 2001, p. 24; Stone *et al.* 2007, p. 133).

Recent assessments of the fish fauna of the lower Colorado River basin have provided additional insight into the importance of nonnative fishes as a threat to native fish including the roundtail chub. The Desert Fishes Team is an ‘‘independent group of biologists and parties interested in protecting and conserving native fishes of the Colorado River basin’’ and includes personnel from the U.S. Forest Service, U.S. Bureau of Reclamation, Bureau of Land Management (BLM), University of Arizona, Arizona State University, the Conservancy, and independent experts (Desert Fishes Team 2003, p. 1). Desert Fishes Team (2003, p. 1) declared the native fish fauna of the Gila River basin to be critically imperiled, citing habitat destruction and nonnative species as the primary factors for the declines. The Desert Fishes Team recommended control and removal of nonnative fish as an overriding need to prevent the decline and ultimate extinction of native fish species within the basin. Clarkson *et al.* (2005) discuss management conflicts as a primary factor in the decline of native fish species in the southwestern United States and declare the entire native fauna as imperiled. The investigators cite nonnative species as the most consequential factor leading to rangewide declines that prevent or negate recovery efforts from being implemented or being successful (Clarkson *et al.* 2005, p. 20). Clarkson *et al.* (2005, p. 20) note that over 50 nonnative species have been introduced into the Southwest as either sport fish or bait fish and are still being actively stocked, managed for, and promoted by both Federal and State agencies as nonnative recreational fisheries. To help resolve the conflicting management mandates of native fish recovery and the promotion of recreational fisheries, Clarkson *et al.* (2005, pp. 22–25) propose the designation of entire watersheds as having either native or nonnative fisheries and the management of watersheds to aggressively meet these goals. Clarkson *et al.* (2005, p. 25) suggest that current management of fisheries within the southwestern United States as status quo will have serious adverse effects on native fish species and affect the long-term viability of these species.

Mash and Pacey (2005, p. 59) concluded, ‘‘The presence of nonnative fishes alone precludes life-cycle completion by the natives. In the absence of nonnatives, however, the natives thrive even in severely altered habitats.’’ This statement appears to apply well to roundtail chub, and the best evidence is provided by the response of the species when nonnative fishes are removed. Marks *et al.* (*in press*) examined the effect of the removal of nonnative species on native species by measuring fish abundance before and after a restoration project to restore flow and chemically remove nonnative fishes (using the chemical rotenone, a fish pesticide) to benefit native fish species including the roundtail chub. They found that roundtail chub abundance increased dramatically after restoration, and attributed most of this response to the removal of nonnative fish species. Marks *et al.* (*in press*) suggested that nonnative fish removal may be a more cost effective method to restore native fish populations than flow restoration, because the cost of chemical renovation was one-tenth the cost of flow restoration at Fossil Creek. Roundtail chub is a stream species that appears to require flow (Service 1987; Marks *et al. in press*). However, AGFD has found that roundtail chub can thrive in pond habitats that are free from nonnative species (AGFD 2009). Similarly, Mueller (2008, p. 2) examined the creation and performance of various nonnative fish-free habitats for bonytail chub, a species closely related to the roundtail chub, and found that recruitment occurred in hatchery-style holding ponds, seemingly a less than optimal habitat for a species that occurs in large rivers. Mueller (2008) concluded, ‘‘In all cases, the common denominator was not physical habitat conditions; it was simply the absence of nonnative predators.’’ As these findings illustrate, habitat may not be the biggest concern for roundtail chub because the species can thrive even in habitats that are seemingly less than ideal, as long as nonnative species are not present. Despite some lack of direct evidence of the effect of predation and recruitment on roundtail chub, the results of removal of nonnative fish clearly demonstrate that either predation or competition is occurring and is a serious threat to the species.

Nonnative species predation may be having an effect on roundtail chub that is known as the ‘‘predator pit’’ hypothesis (Messier 1994, p. 480). This hypothesis proposes that as a population of a species decreases, especially when this happens rapidly, the predators of the species will have an increasing impact on its survival due to the relatively constant consumption amount, and thus increased consumption rate. In situations where predator populations also increase, the effect can be substantial. Given the variety of habitat-altering activities that appear to be affecting roundtail chub throughout the lower Colorado River basin, activities such as dewatering and urbanization are likely reducing roundtail populations. With these reductions, predation by nonnative species create a ‘‘predator pit’’ scenario.

At least two species of crayfish, the red swamp crayfish (*Procambaris clarki*) and the northern or virile crayfish (*Orconectes virilis*), have been introduced into Arizona aquatic ecosystems and are now widely distributed and locally abundant in a broad array of natural and artificial freeflowing and still-water habitats throughout the State, including numerous streams within the historical and current range of the roundtail chub (Inman *et al*. 1998, p. 3; Voeltz 2002, pp. 15–88). Crayfish appear to negatively impact native fishes and aquatic habitats through habitat alteration by burrowing into stream banks and removing aquatic vegetation, resulting in decreases in vegetative cover and increases in turbidity (Lodge *et al.* 1994, p. 1270; Fernandez and Rosen 1996, pp. 10–12). Carpenter (2005, pp. 338–340) documented that crayfish may reduce the growth rates of native fish through competition for food and noted that the significance of this impact may vary between species. Crayfish also prey on fish eggs and larvae (Inman et al. 1998, p. 17). Crayfish alter the abundance and structure of aquatic vegetation by grazing on aquatic and semiaquatic vegetation, which reduces the cover for fish (Fernandez and Rosen 1996, pp. 10–12). Creed (1994, p. 2098) found that filamentous alga (*Cladophora glomerata*) was at least 10-fold greater in aquatic habitat absent crayfish. Filamentous alga is an important component of aquatic vegetation that provides cover and food for fish, including roundtail chub.

Diseases and Parasites

Diseases, specifically parasite infestations, are a threat to the roundtail chub. Asian tapeworm (*Bothriocephalus acheilognathi*) was introduced into the United States via imported grass carp (*Ctenopharyngodon idell*a) in the early 1970s. Asian tapeworm has since become well-established in the Southeast and mid-South and has been recently found in the Southwest. The definitive host in the life cycle of *B. acheilognathi* is cyprinid fishes, and, therefore, it is a potential threat to the roundtail chub as well as to the other native fishes in Arizona. The Asian tapeworm affects fish health in several ways. Two direct impacts are by (1) impeding the digestion of food as it passes through the intestinal track, and (2) causing emaciation and starvation when large numbers of worms feed off of the fish. The Asian tapeworm is present in the Colorado River basin in the Virgin River (Heckman *et al.* 1986, p. 662) and the Little Colorado River (Clarkson *et al.* 1997, p. 66). It has recently invaded the Gila River basin and was found in 1998 in the Gila River near Ashurst-Hayden Dam. Research and monitoring of the effects of Asian tapeworm on a related species, the humpback chub, indicate that this parasite may be a significant cause of mortality because large numbers of Asian tapeworm have been detected in wild humpback chub, and laboratory studies indicate that such infestations cause mortality in Gila species (U.S. Geological Survey 2004, p. 1; 2005, pp. 2–3).

Anchor worm (*Lernaea cyprinacea, Copepoda*), an external parasite, is unusual in that it has little host specificity, infecting a wide range of fishes and amphibians. Severe *Lernaea sp.* infections have been noted in a number of chub populations. Infections of *Lernaea sp*. may have increased in recent years. James (1968, pp. 21–29) found that *Lernaea sp.* was very rare in museum specimens collected prior to the 1930s, but increased in intensity from the 1930s to the 1960s, with roundtail chubs exhibiting the greatest increase (10.8 percent). Hendrickson (1993, pp. 45–46) noted very high infections of *Lernaea sp.* during warm periods in the Verde River, and Voeltz (2002, p. 69) reported that headwater chubs found in Gun Creek in 2000, when surface flow was almost totally lacking, ‘‘showed signs of stress, and many had *Lernaea*, black grub, lesions and an unidentified fungus.’’ Girmendonk and Young (1997, p. 55) concluded that ‘‘parasitic infestations may greatly affect the health and thus population size of native fishes.’’ A die-off of fish including roundtail chub in Trout Creek was likely due to heavy infestations of black grub (*Neascus sp.),* an internal parasite, which may have weakened the fish sufficiently to cause bacteria hemorrhagic septicemia or blood poisoning (Voeltz 2002, p. 33).

The parasite *Ichthyophthirius multifiliis*, or ‘‘Ich’’, is a potential threat to roundtail chub. ‘‘Ich’’ has occurred in some Arizona streams, probably favored by high temperatures and crowding as a result of drought (Mpoame 1982, p. 45). This protozoan becomes embedded under the skin and within the gill tissues of infected fish. When the ‘‘Ich’’ matures, it leaves the fish, causing fluid loss, physiological stress, and sites that are susceptible to infection by other pathogens. If the ‘‘Ich’’ are present in large enough numbers, they can also impact respiration because of damaged gill tissue.

Conservation Actions Relevant to Factor C

All three of the conservation agreements have various provisions to address the threat of nonnative species. The Range-wide Agreement recommends that state conservation agreements include provisions to control (as feasible and where possible) threats posed by nonnative species that compete with, prey upon, or hybridize with roundtail chub. The Arizona Agreement addresses the threat of predation and competition from nonnative species, as well as the threat of disease and parasites, in its provisions for habitat protection. These provisions include: managing detrimental nonnative aquatic species in streams designated for conservation of the subject species; evaluating effectiveness of nonnative management efforts; and managing the spread of infectious diseases and parasites to habitats of the subject species. The Arizona Agreement also includes an indentified deliverable of a native fish management plan that would also serve to address this threat.

The New Mexico Plan includes the following provisions to address the threat of nonnative species:

(1) Determine the distribution and abundance of nonnative species in the San Juan and Gila river watersheds and the physical barriers to their expansion;
(2) Investigate the impacts, particularly competition, habitat modification, and predation, of nonnative species on roundtail chub;
(3) Determine areas of the San Juan and Gila river watersheds where limited nonnative species distribution and abundance may provide opportunities for chub restoration;

(4) Work with sport fish managers to coordinate native and nonnative fish management and identify stream areas expressly for recovery of native species;
(5) When appropriate and feasible, remove nonnative species that present a threat to roundtail, Gila, and headwater chubs;
(6) Prevent the introduction of nonnative species into the watersheds utilizing existing information and programs when possible;
(7) Support efforts to re-establish the historical native aquatic community in ecologically appropriate habitats in the San Juan and Gila river basins utilizing existing programs when possible; and
(8) Inform local resource users about the impacts of nonnative species on roundtail chub.

Specific actions implemented through the conservation agreements to address the threats under Factor C include fisheries management planning efforts and creation of new chub populations in nonnative-fish-free habitats. AGFD convened a Statewide Fish Management Team in 2008, which developed a process to delineate fish management strategies Statewide to address the dual mandates of providing native fish habitat and sport fish angling opportunities for the public. AGDF intends that this process will serve as the deliverable management plan for the Arizona Agreement, and will facilitate sport fish and native fish management decisions throughout Arizona. As discussed in the Status and Distribution of the Lower Colorado River DPS section above, AGFD and NMDGF have created four new populations of roundtail chub, two in streams (Ash Creek and Roundtree Canyon) and two in pond refuges (the Southwest Academy and Gila River Ranch Preserve refuge ponds). These efforts are too new to evaluate their success, but such projects will be essential to reversing the decline of the roundtail chub.

Summary of Factor C

Predation and competition with nonnative aquatic species, and in particular fish, are, along with dewatering of habitat, the most significant threats to the roundtail chub in the lower Colorado River basin. Nonnative aquatic species are a threat to every population of roundtail chub with the possible exception of recent transplants into Roundtree Canyon and Ash Creek, and perhaps Fossil Creek and Aravaipa Creek, based on long-term low levels of occurrence of nonnatives in these streams and presence of natural or manmade fish barriers (Voeltz 2002, p. 47; U.S. Forest Service 2004, p. 1). No attempt has been made to quantify the amount of range of these species affected by parasites; however, parasites have been documented in numerous populations and likely occur throughout the range of these species (Voeltz 2002, pp. 18–19). Although some actions have been implemented through conservation agreements for roundtail chub to address this threat, these actions are either not yet complete or too recently completed to evaluate their success and contribution to the status of the roundtail chub.

Factor D. The Inadequacy of Existing Regulatory Mechanisms.

Existing Regulatory Mechanisms

There are currently no specific Federal protections for roundtail chub, and generalized Federal protections found in forest plans, Clean Water Act dredge and fill regulations for streams, and other statutory, regulatory, or policy provisions have been inadequate to ameliorate the threats to roundtail chub in the lower Colorado River basin. Existing Federal and State regulations and planning have not achieved significant conservation of roundtail chub and its habitat. Although we are aware that roundtail chub occurs on Tribal lands, we do not have sufficient information to evaluate the effectiveness of Tribal management.

As described in Factor C, introductions of nonnative fish are likely a significant threat to roundtail chub. Fish introductions are illegal unless approved by the respective States. However, enforcement is difficult. Many nonnative fish populations are established through illegal introductions. Nine species of fish, crayfish, and waterdogs or tiger salamanders (*Ambystoma pigrimum*) may be legally used as bait in Arizona, all of which are nonnative to the State of Arizona, and several of which are known to have serious adverse effects on native species. The portion of the state in which use of live bait is permitted is limited. The use of live bait is restricted in some of the Gila River system in Arizona (AGFD 2008, p. 28), but the use of live bait species (such as green sunfish) is still permitted in areas such as the Verde River that currently have roundtail chub populations. New Mexico only allows the use of fathead minnow as a live bait-fish in the Gila River drainage in New Mexico, which covers the extent of the range of roundtail chub in the lower Colorado River basin in New Mexico (NMDGF 2008, p. 8). Arizona and New Mexico also continue to stock nonnative sport fishes, including such likely predators and competitors as largemouth bass, channel catfish, rainbow trout, and brown trout, for recreational angling within areas that are connected to habitat of roundtail chub.

Although restrictions on use of live bait help reduce the input of nonnative species into roundtail chub habitat, this does little to reduce unauthorized bait use or other forms of ‘‘bait-bucket’’ transfer (e.g., illegal stock of sport fish, dumping of unwanted aquarium fish) not directly related to bait use. Such ‘‘bait-bucket’’ transfers can be expected to increase as the human population of Arizona increases and as nonnative species remain available to the public through aquaculture and the aquarium trade.

AGFD also regulates nonnative species that can be legally brought into the State. Prohibited nonnative species are put onto the Restricted Live Wildlife List (Commission Order 12–4–406). However, species are allowed unless they are prohibited by placement on the list, rather than the more conservative approach of being prohibited unless specifically allowed. This allows the opportunity for many noxious nonnatives to be legally imported and introduced into Arizona. New Mexico has adopted a more stringent approach; no live animal (except domesticated animals or domesticated fowl or fish from government hatcheries) is allowed to be imported without a permit (NMS 17–3– 32). However, the majority of the roundtail chub’s range in the lower Colorado River basin occurs within Arizona.

Existing water laws in Arizona and New Mexico are inadequate to protect wildlife. The presence of water is clearly a requirement for the roundtail chub. Gelt (2008, pp. 1–12) highlighted the fact that, because existing water laws are old, they reflect a legislative interpretation of the resource that is not consistent with what is known today about hydrology. For example, over 100 years ago when Arizona’s water laws were written, the important connection between groundwater and surface water was not known (Gelt 2008, pp. 1–12). Gelt (2008, pp. 8–9) suggested that preserving stream flows and riparian areas may be better accomplished by curtailing surface water uses rather than groundwater uses, and that the prior appropriation doctrine (appropriation of water rights based upon the water law concept of ‘‘first in use, first in rights’’) may be outdated and impractical for arid areas like Arizona.

The Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701 et seq.) and the National Forest Management Act of 1976 (16 U.S.C. 1600 et seq.) direct the Secretary of the Interior, through BLM, and the U.S. Forest Service, respectively, to prepare programmatic-level management plans to guide long-term resource management decisions. In addition, the U.S. Forest Service is required to manage habitat to provide appropriate ecological conditions to support a diversity of native plant and animal species (36 CFR 219.10). The U.S. Forest Service is the largest landowner and manager of roundtail chub habitat and lists the roundtail chub as a sensitive species in the lower Colorado River basin in the southwestern region (Arizona and New Mexico). The BLM is updating its sensitive species list for Arizona and has indicated they will add roundtail chub. However, a sensitive species designation provides little protection to the roundtail chub because it only requires the U.S. Forest Service and BLM to analyze the effects of their actions on sensitive species, but does not require that they choose environmentally benign actions. Most of these areas where the majority of extant populations of roundtail chub occur are managed by the Forest Service or BLM; thus ongoing management by these agencies has not prevented adverse impacts to roundtail chub habitat. Although both agencies have riparian protection goals, neither agency has specific management plans for the roundtail chub.

Wetland values and water quality of aquatic sites inhabited by the roundtail chub are afforded varying protection under the Federal Water Pollution Control Act of 1948 (Clean Water Act; 33 U.S.C. 1251–1376), as amended; Federal Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands); and section 404 of the Clean Water Act, which regulates dredging and filling activities in waterways. Water quality in the range of the roundtail chub has declined despite these laws. The Arizona Department of Environmental Quality (2008) has identified several streams with water quality problems occupied by roundtail chub. Oak Creek exceeds the total maximum daily load for Escherichia coli (*E. coli*) contamination, due to a combination of recreation, septic systems, urban runoff, and livestock grazing. Boulder Creek exceeds the total maximum daily load for benzene, manganese, mercury, pH, arsenic, copper, and zinc as a result of mining activities. The Verde River exceeds the total maximum daily load for turbidity/sediment due to livestock grazing, urban development, and road use and maintenance. The Arizona Department of Environmental Quality is implementing actions through drainage water quality plans to correct these problems, but they are ongoing and not likely to be resolved in the near future. Our information indicates that the status of the roundtail chub in these areas has declined, although it is unclear whether this is due to these water quality issues (Voeltz 2002, pp. 35, 72).

The NMDGF has adopted a wetland protection policy whereby they do not endorse any project that would result in a net decrease in either wetland acreage or wetland habitat values. This policy may afford some protection to roundtail chub habitat, although it is advisory only and destruction or alteration of wetlands is not regulated by state law. The State of Arizona Executive Order Number 89–16 (Streams and Riparian Resources), signed on June 10, 1989, directs State agencies to evaluate their actions and implement changes, as appropriate, to allow for restoration of riparian resources. Implementation of this regulation may have reduced adverse effects of some State actions on the habitat of the roundtail chub; however, we have no monitoring information on the effects of this State Executive Order, nor do we have information indicating that actions taken under it have been effective in reducing adverse effects to the roundtail chub.

The National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321 et seq.) requires Federal agencies to consider the environmental impacts of their actions. Most actions taken by the U.S. Forest Service, BLM, and other Federal agencies that affect the roundtail chub are subject to NEPA. NEPA requires Federal agencies to describe the proposed action, consider alternatives, identify and disclose potential environmental impacts of each alternative, and involve the public in the decision-making process. However, Federal agencies are not required to select the alternative having the least significant environmental impacts. A Federal action agency may select an action that will adversely affect sensitive species provided that these effects were known and identified in a NEPA document.

The status of roundtail chub on Tribal lands is not well known. Any regulatory or other protective measures for the species on Tribal lands would be at the discretion of the individual Tribe, and non-Tribal entities often have little information with which to evaluate effectiveness. The San Carlos Apache Tribe has developed a fisheries management plan that provides protection to roundtail chub, although there are only two populations that potentially occur on San Carlos Apache lands, representing a very small percentage of the overall range of the species in the lower Colorado River basin. We have limited information on threats to populations of roundtail chub on Tribal lands, but land uses on Tribal lands include livestock grazing, recreation, limited fuel wood harvest, limited agriculture, fisheries and wildlife management, and localized municipal, urban, and rural development and associated water use. The White Mountain Apache Tribe is preparing a fisheries management plan that, when completed, could benefit roundtail chub because 8 of the 31 populations occur wholly or in part on White Mountain Apache Tribal lands.

The State of New Mexico lists the roundtail chub as ‘‘State Endangered’’ under its Wildlife Conservation Act, which prohibits take (New Mexico Wildlife Conservation Act 17–2–41(B)). In the State of New Mexico, an ‘‘Endangered Species’’ is defined as ‘‘any species of fish or wildlife whose prospects of survival or recruitment within the State are in jeopardy due to any of the following factors: (1) The present or threatened destruction, modification, or curtailment of its habitat; (2) overutilization for scientific, commercial or sporting purposes; (3) the effect of disease or predation; (4) other natural or manmade factors affecting its prospects of survival or recruitment within the State; or (5) any combination of the foregoing factors’’ as per New Mexico Statutory Authority 17–2–38.D. ‘‘Take,’’ defined as ‘‘to harass, hunt, capture or kill any wildlife or attempt to do so’’ by New Mexico Statutory Authority 17–2–38.L., is prohibited without a scientific collecting permit issued by the NMDGF as per New Mexico Statutory Authority 17–2–41.C and New Mexico Administrative Code 19.33.6. However, while the NMDGF can issue monetary penalties for illegal take of roundtail chub, the same provisions are not in place for actions that result in loss or modification of habitat (New Mexico Statutory Authority 17–2–41.C and New Mexico Administrative Code 19.33.6).

The roundtail chub is identified on the AGFD draft document (not finalized), Wildlife of Special

Concern (AGFD 2006b, p. 5). The purpose of the Wildlife of Special Concern list is to provide guidance in habitat management implemented by land management agencies. Additionally, the roundtail chub is considered a ‘‘Tier 1b Species of Greatest Conservation Need’’ in the AGFD draft document, Arizona’s Comprehensive Wildlife Conservation Strategy (AGFD 2006c, p. 371). The purpose for the Comprehensive Wildlife Conservation Strategy is to ‘‘provide an essential foundation for the future of wildlife conservation and a stimulus to engage the States, federal agencies, and other conservation partners to strategically think about their individual and coordinated roles in prioritizing conservation efforts’’ (AGFD 2006c, p. 2). A ‘‘Tier 1b Species of Greatest Conservation Need’’ is one that requires immediate conservation actions aimed at improving conditions through intervention at the population or habitat level (AGFD 2006c, p. 32).

As discussed in Factor B, up to one roundtail chub may be taken and possessed per day via angling Statewide in Arizona, with the exception of Fossil Creek, which is catch and release only, from Oct 3, 2009, through April 30, 2010. Take of roundtail chub is also permitted in Arizona via issuance of a scientific collecting permit (Ariz. Admin. Code R12–4–401 et seq.). While the AGFD can seek criminal or civil penalties for illegal take of roundtail chub, the same provisions are not in place for actions that result in destruction or modification of roundtail chub habitat.

Roundtail chub derives some conservation benefit from its co-occurrence with other listed species and critical habitat in the lower Colorado River basin. As an example, Bureau of Reclamation’s interagency consultation (section 7 compliance) on the operation and maintenance of the Central Arizona Project (CAP), a water delivery system designed to bring water from the Colorado River to portions of Pima, Pinal, and Maricopa counties in Arizona, has greatly benefited the species. Biological opinions on the CAP addressed the spread of nonnative aquatic species through the project canals from the Colorado River into the Gila and Santa Cruz River basins (Service 2001, 2008). Conservation measures included in these biological opinions to benefit listed fish and amphibian species (including the spikedace, loach minnow, Gila topminnow, desert pupfish, Gila chub, and Chiricahua leopard frog (*Rana chiricahuensis*)) have benefitted the roundtail chub and likely will into the future. In 2004, nonnative fish were removed from Fossil Creek through chemical renovation to benefit native fish species including the roundtail chub. The Bureau of Reclamation, in cooperation with AGFD, the Service, and the U.S. Forest Service, also installed a fish barrier in lower Fossil Creek to prevent reinvasion of nonnative fish. The Fossil Creek restoration project was a conservation measure included in the CAP biological opinion issued to the Bureau of Reclamation, and it resulted in the creation of the only stable-secure population of roundtail chub currently in existence in the lower Colorado River basin.

Conservation Actions Relevant to Factor D

The Range-wide Agreement recommends that the State plans include provisions to assure adequate regulatory protection for the roundtail chub, flannelmouth sucker, and bluehead sucker within the signatory States, and to install regulatory mechanisms for the long-term protection of habitat (e.g., conservation easements, water rights). The Rangewide Agreement also recommends that States develop multi-State nonnative stocking procedure agreements that protect all three species and potential reestablishment sites from the threat of nonnative species. The Arizona Agreement includes the provision to maintain instream flow by securing habitat through acquisition of water rights or agreements with water rights holders to maintain instream flow. Implementation of these provisions so far has resulted in the U.S. Forest Service application for an instream flow right on Cherry Creek, which contains roundtail chub, and SRP and Conservancy applications to the Arizona Department of Water Resources for instream flow rights on the Verde River. These measures and actions may result in further regulatory protection for roundtail chub by legally protecting flows for the species.

Summary of Factor D Existing regulations within the range of the roundtail chub address the direct take of individuals without a permit, and unpermitted take is not thought to be a threat to roundtail chub. However, Arizona and New Mexico statutes do not provide protection of habitat and ecosystems. Currently, there are no regulatory mechanisms in place that specifically target the conservation of roundtail chub or its habitat. General regulatory mechanisms protecting the quantity and quality of water in riparian and aquatic communities are inadequate to protect water resources for the roundtail chub, particularly in the face of the significant human population growth expected within the historical range of the chub discussed under Factor A. Conservation actions defined in existing conservation agreements may provide some additional regulatory protection, in particular through development of instream flow rights to protect habitat for the roundtail chub, but no instream flow rights have yet been acquired, although several applications for specific waters have been submitted.

Factor E. Other Natural or Manmade Factors Affecting Its Continued Existence.

Fragmented Populations and Stochastic Events

The rarity of roundtail chub increases the possible extinction risk associated with stochastic events such as drought, flood, and wildfire. Roundtail chub populations have been fragmented and isolated to smaller stream segments and may be vulnerable to natural or manmade factors (e.g., drought, groundwater pumping) that might further reduce their population sizes. Maintaining several populations with relatively independent susceptibility to threats is an important consideration in the long-term viability of a species (Shaffer 1987; Goodman 1987). Redundant populations provide security from catastrophic events or repeated recruitment failure. For example, consider that a single hypothetical population has a probability of extinction from a catastrophic event of 10 percent in 200 years. If two populations are independent, the probability of both going extinct is 1 percent (0.12). For three populations, the probability reduces to 0.1 percent (0.13). Even with an extinction probability of 25 percent for one population, the probability of extinction for two and three populations is 6.3 percent and 1.6 percent, respectively (Casagrandi and Gatto 1999). Fagan *et al.* (2002) determined that individual roundtail chub populations have a 0.41 percent probability of extirpation given current status and levels of fragmentation and isolation. Providing for multiple populations that are secure and stable (as defined above in Table 1, a population that is recruiting with multiple age classes and that is free from threats) in a single drainage basin will provide increased redundancy and reduce the likelihood of extirpation. We consider a particular basin or management area to be at risk of extirpation if there are fewer than a minimum of two stable-secure populations because any single population can be eliminated by stochastic events or catastrophic disturbance, such as fire.

We only consider roundtail chub to be stable-secure in one stream, Fossil Creek.

In general, Arizona is an arid State; about one-half of Arizona receives less than 10 in. (25 cm) of rain a year. Dewatering and other forms of habitat loss have resulted in fragmentation of roundtail chub populations. We anticipate that water demands from a rapidly increasing human population may further reduce habitat available to this species, and could further fragment populations. In examining the relationship between species distribution and extinction risk in southwestern fishes, Fagan et al. (2002, p. 3250) found that the number of occurrences or populations of a species is less significant a factor in determining extinction risk than is habitat fragmentation. Fragmentation of habitat may also cause the roundtail chub to be vulnerable to extinction from threats of further habitat loss and competition from nonnative fish because immigration and recolonization from adjacent populations is less likely. The risk of extirpation of individual populations of this species appears to be quite high given the degree of fragmentation (Fagan *et al.* 2002, p. 3254), that only one population is considered stable and secure, and that many threats are predicted to increase in severity in the future.

Climate Change

Several recent studies predict continued drought in the southwestern United States, including the lower Colorado River basin, due to global climate change. Seager *et al.* (2007, pp. 1181–1184) analyzed 19 different computer models of differing variables to estimate the future climatology of the southwestern United States and northern Mexico in response to predictions of changing climatic patterns. All but one of the 19 models predicted a drying trend within the Southwest (Seager *et al.* 2007, p. 1181). A total of 49 projections were created using the 19 models, and all but 3 predicted a shift to increasing aridity (dryness) in the Southwest as early as 2021–2040 (Seager *et al.* 2007, p. 1181). Recently published projections of potential reductions in natural flow in the Colorado River basin by the mid- 21st century range from approximately 45 percent by Hoerling and Eischeid (2006, p. 3989) to approximately 6 percent by Christensen and Lettenmaier (2006, pp. 3727–3729). The U.S. Climate Change Science Program recently completed a report entitled ‘‘Abrupt Climate Change, A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research’’ (U.S. Climate Change Science Program 2008a). Regarding the southwest United States, the summary and findings concluded: ‘‘Climate model studies over North America and the global subtropics indicate that subtropical drying will likely intensify and persist in the future due to greenhouse warming. This drying is predicted to move northward into the southwestern United States. If the model results are correct, then the southwestern United States may be beginning an abrupt period of increased drought’’ (U.S. Climate Change Science Program 2008b, p. 2).

If predicted effects of climate change result in persistent drought conditions in the Colorado River basin similar or worse than those seen in recent years, water resources will become increasingly taxed as supplies dwindle and demand stays the same or increases. Likewise, there would be increased demand on surface and groundwater supplies in Arizona. Clearly, permanent water is crucial for the continued survival of native fish in the region, including roundtail chub. Essentially the entire range of the roundtail chub in the lower Colorado River basin is predicted to be at risk of becoming more arid (Seager *et al.* 2007, pp. 1183–1184), which has severe implications to the integrity of aquatic and riparian ecosystems and the water that supports them.

Perennial streams in the region may become intermittent and streams that are currently intermittent may become unsuitable or dry completely.

Changes to climatic patterns may warm water temperatures, alter stream flow events, and increase demand for water storage and conveyance systems (Rahel and Olden 2008, pp. 521–522). Warmer water temperatures across temperate regions are predicted to expand the distribution of existing aquatic nonnative species by providing 31 percent more suitable habitat for aquatic nonnative species. This conclusion is based upon studies that compared the thermal tolerances of 57 fish species with predictions made from climate change temperature models (Mohseni *et al.* 2003, p. 389). Eaton and Scheller (1996, p. 1111) reported that while several cold-water fish species in North America are expected to have reductions in their distribution from effects of climate change, several warmwater fish species are expected to increase their distribution. In the southwestern United States, this situation may occur where water persists but water temperature warms to a level suitable for nonnative species that were previously physiologically precluded from occupation of these areas. Species that are particularly harmful to roundtail chub populations such as the green sunfish, channel catfish, largemouth bass, and bluegill are expected to increase their distribution by 7.4 percent, 25.2 percent, 30.4 percent, and 33.3 percent, respectively (Eaton and Scheller 1996, p. 1111). Rahel and Olden (2008, p. 526) expect that increases in water temperatures in drier climates such as the southwestern United States will result in periods of prolonged low flows and stream drying. These effects from changing climatic conditions may have profound effects on the amount, permanency, and quality of habitat for the roundtail chub. Warmwater nonnative species such as red shiner, common carp, mosquitofish, and largemouth bass are expected to benefit from prolonged periods of low flow (Rahel and Olden 2008, p. 527).

Rahel *et al.* (2008, p. 551) examined climate change models, nonnative species biology, and ecological observations, and concluded that climate change could foster the expansion of nonnative aquatic species into new areas, magnify the effects of existing aquatic nonnative species where they currently occur, increase nonnative predation rates, and heighten the virulence of disease outbreaks in North America. Many of the nonnative species have similar, basic ecological requirements as our native species, such as the need of nonnative fish species for permanent or nearly permanent water. Rahel *et al.* (2008, pp. 554–555; and from Carveth *et al.* 2006, p. 1435) found that climate change will likely favor nonnative fish species such as largemouth bass, yellow bullhead, and green sunfish over roundtail chub, in part because they have higher temperature tolerances. Also, drying of stream channels will create less habitat and greater competition due to limited space and habitat. Thus climate change can eliminate roundtail chub habitat through at least two mechanisms: directly, by drying up aquatic habitats due to decreases in precipitation and stable or increasing human demand for water resources; and indirectly by improving conditions for nonnative species, increasing their proliferation, and thereby increasing the threat from nonnative fish predation and competition.

Rahel *et al.* (2008, p. 555) also noted that climate change could facilitate expansion of nonnative parasites. This could be an important threat to roundtail chub. Optimal Asian tapeworm development occurs at 77–86 °F (25–30 °C) (Granath and Esch 1983, p. 1116), and optimal anchorworm temperatures are 73–86 °F (23–30 °C) (Bulow *et al.* 1979, p. 102). Cold water temperatures in parts of the range of the roundtail chub may have prevented these parasites from completing their life cycles and limited their distribution. Warmer climate trends could result in warmer overall water temperatures, increasing the prevalence of these parasites.

The effects of the water withdrawals discussed above may be exacerbated by the current, long-term drought facing the arid southwestern United States. Philips and Thomas (2005, pp. 1–4) provided streamflow records that indicate that the drought Arizona experienced between 1999 and 2004 was the worst drought since the early 1940s and possibly earlier. The Arizona Drought Preparedness Plan Monitoring Technical Committee (2008) assessed Arizona's drought status through June of 2008 in watersheds where the roundtail chub occurs or historically occurred. They found that the Verde and San Pedro watersheds continue to experience moderate drought (Arizona Drought Preparedness Plan Monitoring Technical Committee 2008), and the Salt, Upper Gila, Lower Gila, and Lower Colorado watersheds were abnormally dry (Arizona Drought Preparedness Plan Monitoring Technical Committee 2008). Ongoing drought conditions have depleted recharge of aquifers and decreased baseflows in the region. While drought periods have been relatively numerous in the arid Southwest from the mid-1800s to the present, the effects of human-caused impacts on riparian and aquatic communities may compromise the ability of these communities to function under the additional stress of prolonged drought conditions.

Conservation Actions Relevant to Factor E

The Arizona Agreement includes provisions to address the threat of population fragmentation, identifying the need to maintain connectivity, or at least gene flow, even by artificial means, between populations. If connectivity between occupied habitats cannot be maintained via natural connection, the Arizona Agreement recommends considering the practice of moving individuals of the subject species between fragmented populations. Further, reducing existing stressors by implementing the conservation agreements will give existing populations additional resiliency to face the stresses presented by climate change.

Summary of Factor E

Threats to roundtail chub are magnified by the fragmentation of existing populations. All but one model evaluating changing climatic patterns for the southwestern United States and northern Mexico predict a drying trend for the region (Seagar *et al.* 2007, pp. 1181–1184). We acknowledge that drought and the loss of surface water in riparian and aquatic communities are related to changing climatic conditions (Seagar *et al.* 2007, pp. 1181–1184). The extent to which changing climate patterns will affect the roundtail chub is not known with certainty at this time. However, threats to the roundtail chub identified in Factors A and C will likely be exacerbated by changes to climatic patterns in the southwestern United States due to increasing drought and reduction of surface waters if the predicted patterns are realized.

CONSERVATION MEASURES PLANNED OR IMPLEMENTED

Conservation Agreements

As discussed in the ''Conservation Actions Relevant to Factor A'' section above, there are three wide-ranging plans that address the ongoing conservation of the roundtail chub. The Utah

Department of Natural Resources' Range-wide Agreement was finalized and signed by all the Colorado River basin states in 2004. The Range-wide Agreement depends heavily on individual State plans for its implementation. The objectives of the Range-wide Agreement are to:

(A) Establish or maintain populations sufficient to ensure the conservation of each species within the state;
(B) Establish or maintain sufficient connectivity between populations so that viable metapopulations are established or maintained;
(C) As feasible, identify, significantly reduce or eliminate threats to the conservation of these species.

To meet its obligations under the Range-wide Agreement, New Mexico completed a recovery plan for the roundtail chub in November of 2006, the ''Colorado River Basin Chubs Recovery Plan'' (New Mexico Plan) (Carman 2006, p. 39). The New Mexico Plan includes a management strategy with the goal of establishing roundtail chub populations that are secure and self-sustaining throughout their historical ranges in New Mexico, and the objective for at least one sufficient, self-sustaining, secure population of roundtail chub in the mainstem of the Gila River in New Mexico (Carman 2006, p. 49). The New Mexico Plan management strategy also includes specific and comprehensive management issues and strategies with corresponding implementation tasks and a timeline for completion. The implementation tasks provide a comprehensive list of conservation measures including: compiling information on status and potential habitat; improving knowledge of historical and current population dynamics; creating refuge populations of chub lineages; restoring and securing habitats; if necessary, augmenting populations; if possible, establishing additional populations; restricting angling take of headwater chub; controlling nonnative species; identifying and reducing information gaps; and establishing agreements and partnerships to implement the plan (Carman 2006, pp. 55–57). Actions taken to date in implementation of the New Mexico Plan include the creation of a new refuge population of roundtail chub at the Conservancy's Gila River Preserve farm pond in 2008 using offspring of wild-caught Verde River fish from the AGFD Bubbling Ponds Fish Hatchery. The NMDGF plans to complete health and genetic studies on these fish, and if appropriate, their offspring will be stocked into the mainstem Gila River in New Mexico. The NMDGF has also been working with partners to secure habitat through purchases and land management. In 2007, the Department and the Conservancy purchased 168 ac (68 ha) of riparian and river habitat in the Gila- Cliff Valley.

The goal of the Arizona Agreement is to ensure the conservation of roundtail chub, headwater chub, flannelmouth sucker, Little Colorado River sucker, bluehead sucker, and Zuni bluehead sucker populations throughout Arizona. The Arizona Agreement's objective is to address and ameliorate the five listing factors in accordance with section 4(a)(1) of the Act; the Arizona Agreement objectives also correspond to those in the Range-wide Agreement (see above). The Arizona Agreement includes a strategy that is comprehensive and includes numerous conservation strategy tasks. Key tasks include: create a management plan; create a Statewide management team; conduct status assessments; identify threats; conduct research; secure, enhance, maintain, and create habitat; manage detrimental nonnative fish/ aquatic species; manage the spread of infectious diseases and parasites; enhance or restore connectedness and opportunities for migration; create, maintain and evaluate fish refugia; establish and enhance populations; monitoring; and outreach (AGFD 2006a, pp. 45–52). The Arizona Agreement also includes success criteria, including: population stability criteria for sizes and numbers of populations to maintain roundtail chub; threat reduction success criteria, to determine if threats have been adequately mitigated or eliminated, and monitoring to evaluate status and trend of populations, and determine if habitat is being adequately maintained.

AGFD has established a Statewide Management Team to implement the Arizona Agreement; signatories include the Bureau of Reclamation, the Hualapai Tribe; SRP; BLM; the Arizona State Lands Department; the Arizona Department of Water Resources; the Conservancy; the U.S. Forest Service; and the Service. Under the Arizona Agreement, AGFD and its partners have implemented several conservation actions that have benefited the roundtail chub, including stocking roundtail chub into two new habitats that are free from nonnative fishes, Roundtree Canyon and Ash Creek. These stockings are too new to evaluate whether roundtail chub has become established, but if successful, these efforts will help conserve the species by creating two new populations that are largely free from significant threats. AGFD plans to establish another new population of roundtail chub in Houston Creek in 2009. AGFD is also working with various partners to develop operating criteria for Alamo Dam on the Bill Williams River to conserve roundtail chub, and is finalizing broodstock and fishery management plans, which will guide the maintenance and propagation of different stocks for use in restoration of populations throughout the range of the DPS and management of individual population units, management areas, and conservation units.

The Range-wide Agreement and the Arizona Agreement depend on goodfaith efforts from signatories for their implementation, and identify the need to develop funding sources for their implementation. Likewise, the New Mexico Plan commits to using existing resources and funding sources, to the extent possible, to implement the plan, and also identifies the need for additional sources for full implementation. No funding agreements are in place to support these efforts. Although a few conservation actions have been implemented to benefit roundtail chub, as discussed above, the Range-wide Agreement, the Arizona Agreement, and the New Mexico Plan, and their comprehensive lists of tasks, which if fully implemented would significantly aid in the conservation of roundtail chub, are in the early stages of implementation at this point in time. Specific actions identified in these plans, either planned or implemented, that address individual threats are identified in Factors A to E as appropriate.

The Arizona Agreement has resulted in two new populations of roundtail chub, one in a 1.2-mi (2-km) tributary to the Verde River, Roundtree Canyon, and one in a 0.6-mi (1-km) tributary of the Salt River, Ash Creek. These translocations are too new to evaluate their success, having been completed in 2008 and 2007 respectively, but they could potentially benefit the species. AGFD is also planning to execute a translocation into a second tributary of the Verde River, Houston Creek, on the Tonto National Forest, in 2009. Another conservation measure being undertaken as a result of the conservation agreements is the establishment of refuge populations and broodstock. Refuge or sanctuary populations have proven to be important in the conservation of native fish in the Southwest by creating predator-free habitats (Mueller 2008), and use of broodstock populations has prevented the extinction of bonytail (Hedrick *et al.* 2000). AGFD has developed broodstock management plans for the Verde River and Chevelon Creek (Cantrell 2009, p. 5). Refuge populations provide both broodstock and a secure population to preserve the genetic integrity of a population. AGFD and the NMDGF recently created a refuge population in New Mexico at the Conservancy Gila River Preserve refuge pond near the Gila River. AGFD has also created a refuge at the Southwest Academy on Wet Beaver Creek near Camp Verde, Arizona. Both of these refuges were created with Verde River broodstock from a broodstock population at the AGFD Bubbling Ponds fish hatchery. AGFD plans to create additional refuge/broodstock populations for other conservation management units, with a minimum of one for each management area (Cantrell 2009, p. 5).

SRP has completed two habitat conservation plans (HCPs) for its operation of Roosevelt Dam and Lake and its operation of Horseshoe and Bartlett reservoirs (SRP 2006, 2008, 2009). Through implementation of the Roosevelt HCP, SRP has permanently protected and will manage land and water rights for more than 2,000 ac (809 ha) of riparian and aquatic habitat along Tonto Creek and the middle Gila, lower San Pedro, and Verde rivers. Conservation measures on these properties, such as increasing instream flows, excluding livestock, improving channel integrity, excluding vehicle and off-road vehicle traffic, abating wildfires, and promoting riparian ecosystem health, will continue in perpetuity and will directly benefit native fishes, including the roundtail chub. For example, one such SRP-owned and maintained property is the Camp Verde Riparian Preserve near Camp Verde, Arizona, on the Verde River, which contains a portion of the Verde River occupied by roundtail chub (SRP 2006, pp. 26–28).

The HCP for Horseshoe and Bartlett Reservoirs specifically covers the roundtail chub and includes numerous minimization and mitigation measures that will benefit the species, including: rapid drawdown of Horseshoe Lake annually to disadvantage nonnative fish species by adversely affecting the recruitment and growth of these species; providing funding to AGFD for creation and maintenance of fish rearing facilities at its Bubbling Ponds State Fish Hatchery; providing funding and support for native fish stocking, including stocking of roundtail chub; watershed management efforts that serve to maintain quality and quantity of instream flows; native fish monitoring; and public outreach (SRP 2008, pp. 193–201). SRP is also a signatory to the Arizona Agreement, and in this capacity, has funded roundtail chub genetics research and development of roundtail chub broodstock. SRP also works with AGFD to salvage roundtail chub from its canals (SRP 2009, pp. 6–7).

In summary, conservation agreements and associated plans have been developed for roundtail chub in the lower Colorado River basin, and some actions have been implemented as a result that benefit and help conserve the roundtail chub, such as the establishment of new populations in nonnative fish-free habitats and the development of broodstock for use in establishing and augmenting populations. These plans also include numerous actions to help reduce the threats to the roundtail chub. While we recognize the importance of working with our partners in conserving the roundtail chub through the implementation of these plans, and recognize that if implemented, they will greatly assist in the conservation of roundtail chub, these agreements have only recently been completed and are in the early stages of implementation.

SUMMARY OF THREATS

The following discussion illustrates how the threats to the species have affected and are affecting the roundtail chub across the DPS. Based on museum records documented in Voeltz (2002, Appendices), we suspect that the roundtail chub retained much of its historical distribution in the lower Colorado River basin within the United States up to and likely through the 1920s. Activities such as the construction of dams and water diversions that occurred throughout the early to mid-1900s for agriculture and regional economic development likely eliminated surface flow throughout stream reaches with occupied habitat, which led to widespread extirpations of roundtail chub populations in areas such as the lower Gila and Salt Rivers in Arizona. After the period of dam construction and the subsequent creation of reservoirs, widespread nonnative fish stocking efforts ensued throughout Arizona beginning in mid 1900s. The effects from this influx of nonnative species throughout the Southwest resulted in significant declines in native fish and ranid frog distribution and abundance, and the subsequent listing of 19 of Arizona's 31 native fish species throughout the last 35 years (see discussion in the ''Nonnative Species'' section above).

Roundtail chub in the lower Colorado River basin have been eliminated from approximately 68-82 percent of their former range (Voeltz 2002, p. 83). Currently, there are three specific Management Areas of the DPS. Management Area A contains three river basins with the same lineage of roundtail chub: The Gila, Salt, and Verde rivers (Dowling *et al.* 2008). However, these three basins have very limited connectivity between them today, and the status of each basin may best be described separately. We will therefore discuss each of these river basins separately to better understand the status of the Management Area.

The roundtail chub populations in the Verde River basin have the best hydrological connectivity between populations of any basin and the only ''stable-secure'' population, in Fossil Creek (Table 2). However, the Verde River is fragmented due to the presence of Horseshoe and Bartlett reservoirs. Fossil Creek was restored in 2004, and has been stocked with native fishes including roundtail chub. Of the other five natural populations in the Verde River, one is extirpated, two are ''stable-threatened'' and two are ''unstable-threatened.'' Reproduction and recruitment is documented in the two ''stable-threatened'' populations, but even in these, appears sporadic over time (Brouder et al. 2001, p. 9). As discussed above (see the Summary of Factors Affecting the Species section), the Verde River is experiencing threats from numerous land uses, especially water withdrawal with increasing demand for the Big Chino aquifer, the source of the Verde River. Nonnative species are present in all populations with the exception of Fossil Creek. Throughout the Verde River basin, populations seem at risk of not achieving long-term persistence due to threats, as only sporadic recruitment documented.

The Salt River populations are difficult to assess due to land ownership. The success of Tribal fisheries management plans is uncertain. The San Carlos Apache Tribe Fisheries Management Plan is complete, but the species has limited occurrence on that reservation. The White Mountain Apache Tribe has begun work on a fisheries management plan, which is not yet complete. Tribal management affects all but two populations in the Salt River basin. Of the two completely non-Tribal populations, one is ''stable-threatened'' and one is ''unstable-threatened.'' Cherry Creek, the lone ''stable-threatened'' population, is disconnected from other populations in the Management Area, and a single stochastic event, such as wildfire, which has recently affected nearby populations, could eliminate the population.

The roundtail chub populations in the Gila River are almost completely extirpated, with the only ‘‘stable-threatened’’ population in Aravaipa Creek. Aravaipa Creek is protected by fish barriers, erected by the Bureau of Reclamation as a result of the CAP biological opinions (Service 2001, 2008). Thus the roundtail chub in Aravaipa Creek has also benefited from its co-occurrence with the Federally listed spikedace and loach minnow. Aravaipa Creek has also benefitted from other conservation actions, including those undertaken through conservation agreements, such as actions of the Conservancy taken for its protection, discussed above (see Conservation Actions Relevant to Factor A). But nonnative fish species do occur above the barrier in Aravaipa Creek and could conceivably spread. The only other populations in the Management Area are Eagle Creek and the upper Gila River in New Mexico. Roundtail chub in both of these locations has become very rare in recent years (Carman 2006, p. 7; Cantrel 2009, p. 9). Both of these populations are subject to numerous threats, including abundant nonnative species and dewatering due to ongoing mining operations and potential water projects resulting from recent water rights settlements.

Management Area A is thus at a high risk of extirpation for several reasons. The management area is made up of fractured basins, the Gila, Salt, and Verde Rivers. Many populations have been extirpated, and roundtail chub in Eagle Creek and the Upper Gila River has become very rare. A number of populations are on Tribal lands and are difficult to evaluate in terms of status and future management. Two populations are fairly well protected and have a stable status, Fossil and Aravaipa Creeks. However, these two locations are no longer connected, and we find that their current status is largely due to special management resulting from their co-occurrence with already listed fish species. All of the other populations apart from Fossil and Aravaipa Creeks in Management Area A are likely at significant risk from Factors A and C, and in particular, predation from nonnative fish species and dewatering.

Management Area B is the Bill Williams River Basin. Streams in the Bill Williams Management Area are highly fragmented and subject to summer drying, even under normal conditions, because the area is in the driest part of the DPS (Green and Sellers 1964, Figs. 3–5). It is likely that all populations in Management Area B are fragmented and isolated during the dry season. Remaining populations face increasing groundwater development particularly in the Boulder Creek subbasin, and in Kirkland Creek in particular. Only four of the nine extant populations are ‘‘stable-threatened’’ and those are in isolated portions of the drainage. Trout Creek is completely isolated, and the Big Sandy River is extirpated. The Burro Creek drainage, which includes Boulder and Conger Creeks, has some redundancy, but effluent from mining operations and the presence of green sunfish, red shiner, and yellow bullhead in Boulder Creek pose a threat to these populations. The Santa Maria sub-basin contains three populations, including Kirkland and Sycamore Creeks, all of which are considered ‘‘unstable-threatened’’ and at risk from increased groundwater pumping and the presence of nonnative fish species. According to AGFD, these streams may dry completely in drought and are more vulnerable to the effects of climate change (A. Clark, AGFD, pers. comm. 2009). Thus, Management Area B is a collection of highly isolated, threatened populations, in a very dry region of the DPS.

Management Area C is the Little Colorado River Basin. Only two populations remain: Clear Creek (East Clear Creek) and Chevelon Creek. Both are ‘‘unstable-threatened.’’ Recent surveyors have commented with surprise that these populations persist. For example, Clarkson and Marsh (2005b, p. 9) remarked that the occurrence of roundtail chub and juvenile roundtail chub in Clear Creek was shocking given the lack of occurrence in surveys a year before, and especially given the co-occurrence and dominance of nonnative fish species in the area. The authors would not even speculate on why this rare situation existed, but noted that in similar situations in the Southwest, ‘‘natives eventually decline and succumb in the presence of nonnative fish populations (Marsh and Pacey 2005).’’ Further, they found that other natives including speckled dace (*Rhinichthys osculus*), bluehead sucker, and Little Colorado spinedace (*Lepidomeda vittata*) were absent from Clear Creek, which Clarkson and Marsh (2005b, p. 9) state ‘‘is likely testament to the continuing deterioration of the native fish fauna in this area.’’ Threats to these two populations include both nonnative species and water use. The aquifer that feeds these streams in their lower reaches has recently been the subject of study for its use as a water supply for nearby mining operations and future development in towns of the region such as Flagstaff, Winslow, and Holbrook. Therefore, further strain on these systems from increased surface and groundwater diversions is likely. Of the three management areas, Management Area C appears to be the most threatened and has the poorest status. Given the lack of redundancy and resiliency in these populations, the loss of the two populations seems very likely in the near future without aggressive conservation to reduce threats.

For species that are being removed from candidate status:
____Is the removal based in whole or in part on one or more individual conservation efforts that you determined met the standards in the Policy for Evaluation of Conservation Efforts When Making Listing Decisions (PECE)?

RECOMMENDED CONSERVATION MEASURES

AGFD (2006) and Carman (2007) documents described above provide comprehensive lists of conservation measures for roundtail chub. Briefly, the key conservation measures include:

- Establish agreements and partnerships to achieve roundtail chub conservation;
- Improve survey information to better establish population trends;
- Create and maintain refugia for management units;
- Protect and improve habitat (instream flow, physical properties, chemical properties);
- Implement control of nonnative species;
- Reestablish roundtail chub into formerly occupied habitats;
- Improve knowledge of the species and its needs through research;
- Improve public knowledge of the species and the need for its conservation.

LISTING PRIORITY

THREAT			
Magnitude	Immediacy	Taxonomy	Priority
High	Imminent	Monotypic genus Species Subspecies/population	1 2 3

	Non-imminent	Monotypic genus Species Subspecies/population	4 5 6
Moderate to Low	**Imminent** Non-imminent	Monotypic genus Species **Subspecies/population** Monotypic genus Species Subspecies/population	7 8 **9** 10 11 12

Rationale for listing priority number:

Magnitude:
This 2010 assessment utilizes information from 2009 12-Month Finding on a Petition to List a Distinct Population Segment of the Roundtail Chub (*Gila robusta*) in the Lower Colorado River Basin (74 FR 32352). We conclude that the roundtail chub now occurs in 33 stream segments and appears to have occurred in at least 41 historically. We now consider 1 population ‘‘stable-secure,’’ 8 populations ‘‘stable-threatened,’’ 13 populations ‘‘unstable-threatened,’’ and 9 populations ‘‘unknown.’’ Ten populations remain extirpated. Many of the currently extant streams where roundtail chub now occur are fragmented, and many and are small, isolated stream segments. We estimate the extant stream segments represent only 18 to 32 percent of the species’ former range (approximately 800 km (500 miles) to 1350 km (840 mi) of 3050 km (1895 mi) in Arizona and New Mexico (Voeltz 2002).

Although the remaining populations are fragmented and isolated, and threatened by a combination of factors, the remaining roundtail chub populations have exhibited long-term persistence, and existing data indicate that status in 9 of the 33 currently extant stream segments are now considered stable. Recent surveys indicate that 24 populations continue to persist, including the populations considered unstable. A primary threat to these species is predation and competition from non-native aquatic organisms, which, once established, are extremely difficult to eradicate. As human population density increases in Arizona, demands on local water sources can be expected to increase to the detriment of aquatic habitats, further threatening native fish faunas, including the roundtail chub. The fragmented nature and rarity of existing populations also makes them vulnerable to extinction from other natural or manmade factors such as drought and wildfire. However, both the threat of nonnative species and habitat destruction appear to be of a lower magnitude than previously thought because all populations are continuing to persist, and have persisted over approximately 15 years of surveys on average, and some populations such as the upper Gila River are now considered stable. Although existing regulatory mechanisms do not appear to be adequate for addressing the impact of nonnative fish and also have not removed or eliminated the threats that continue to be posed in relation to habitat destruction or modification, a recently completed statewide conservation agreement (AGFD 2006) should begin to address and minimize these threats and protect habitat. Several projects are currently planned by the signatories of the agreement that will help conserve the species (AGFD 2008). Therefore, because many of the populations now appear to be stable or at least able to persist over the long-term in the face of threats, we find that the threats facing this species are of a moderate magnitude.

Imminence:
Habitat destruction and modification has occurred, and continues to occur, as a result of dewatering, impoundment, channelization, and channel changes caused by alteration of riparian vegetation and watershed degradation from mining, grazing, roads, water pollution, urban and suburban development, groundwater pumping, and other human actions. Pressures to withdraw water in the Verde River basin for human use are on-going and increasing. The threat of wildfire to the species continues to be imminent. The lower Colorado River drainage is in the midst of a long-term, on-going drought, causing stream flows to be at record lows which further reduces available habitat for the roundtail chub. Current land management practices continue to degrade the habitat of roundtail chub by contributing sediment to the streams. Thus, these threats are on-going and therefore, imminent.

Rationale for Change in Listing Priority Number (insert if appropriate)

_yes__ Have you promptly reviewed all of the information received regarding the species for the purpose of determining whether emergency listing is needed?

Is Emergency Listing Warranted? No. Given the information we currently have on the status of the species, we do not believe emergency listed is warranted. While the situation is serious, we do not believe that it rises to the level of requiring emergency listing. The long-term effect of the on-going drought on the roundtail chub is unknown. We are working with AGFD and NMGFD and various landowners on implementation of the conservation strategy. We believe that the current status of the species combined with these efforts to conserve the species preclude emergency listing at this time. We anticipate that implementation of this conservation agreement will conserve the species. The conservation agreement has already resulted in better monitoring that is improving assessments of roundtail chub status, and efforts to install barriers and remove nonnative fishes from roundtail chub habitats are in the planning stages.

DESCRIPTION OF MONITORING

Monitoring is on-going by AGFD, NMDGF, and U.S. Forest Service. We coordinate with the U.S. Forest Service and the states to track the status of roundtail chub on a semi-annual basis. Completion of the status review in 2002 (Voeltz 2002) resulted in new surveys and the identification of gaps in existing survey information. Implementation of the AGFD conservation strategy is improving monitoring for the species. Likewise, the NMDGF's implementation of their recovery plan continues to improve monitoring.

COORDINATION WITH STATES
Indicate which State(s) (within the range of the species) provided information or comments on the species or latest species assessment: AGFD and NMDGF have both provided information used in this assessment. Both Arizona and New Mexico have identified the roundtail chub as a "Species of Greatest Conservation Need" in their "Comprehensive Wildlife Conservation

Strategy."

Indicate which State(s) did not provide any information or comments: N/A

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APPROVAL/CONCURRENCE: Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve: ______________________________ May 21, 2010

Acting Regional Director, Fish and Wildlife Service — Date

Concur: ______________________________ ACTING

Director, Fish and Wildlife Service — Date: October 22, 2010

Do not concur: ______________________________ ____________

Director, Fish and Wildlife Service — Date

Director's Remarks:

Date of annual review:
Conducted by: